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Notes for Libraries and Research Institutes

FORMER ISSUES OF AGRICULTURAL JOURNAL

So many requests are received from abroad for parts of the "Agricultural Journal" which were never published that the following list of all issues published and those which are not now available is given for reference. Attention is especially directed to Volume 7 which had only one part :—

Vol.			Vol.		
1.	3 numbers,	1928.	13.	4 numbers,	1942.
2.	4 ,,	1929.	14.	4 ,,	1943.
3.	3 ,,	1930 (none).	15.	4 ,,	1944.
4.	4 ,,	1931.	16.	4 ,,	1945.
5.	2 ,,	1932 (none of No. 2).	17.	4 ,,	1946 (none of No. 1).
6.	2 ,,	1933.	18.	4 ,,	1947 (none of No. 1).
7.	1 ,,	1934.	19.	4 ,,	1948 (Nos. 3 and 4 form a double issue).
8.	4 ,,	1935-7 (none of No. 4).			
9.	4 ,,	1938 (none of Nos. 2, 3 and 4).	20.	4 ,,	1949.
10.	4 ,,	1939 (none of Nos. 2 and 4).	21.	3 ,,	1950 (none of Nos. 1 and 2 combined).
11.	4 ,,	1940 (none)			
12.	4 ,,	1941 (none of Nos. 1 and 2).	22.	1 ,,	1951.

ISSUES OF AGRICULTURAL CIRCULAR

Numbers and year of issue of the "Agricultural Circular" :—

Vol. 1, 1920, 12 numbers. Vol. 4, 1923, 1 number.
2, 1921, 5 ,, 5, 1924-5, 2 numbers.
3, 1922, 4 ,,

As number 4 of Vol. 3 was printed as "Volume 4" and number 1 of Vol. 4 as "Volume 5" it would appear from an inspection of a complete set that Volume 4 comprised only a number 4 and that there were two issues of Volume 5, No. 1.

ANNUAL BULLETINS

The Annual Bulletin of Divisional Reports ran from 1931 to 1938 and was then discontinued.

OLD ISSUES OF AGRICULTURAL BULLETINS

Free copies of the following Bulletins are available to Colonial Departments of Agriculture research institutes and bona fide planters within the Colony.

No. 1. Sisal Hemp in Fiji, 1911.
3. Rhinoceros Beetle in Samoa, 1912.
4. The Banana in Fiji, 1912.
5. Scale Insect on Bananas, 1913.
6. Lemon Grass, 1913.
7. A Mission to Java for a Coleopterous Pest of Bananas, 1914.
8. Coconut Experiments, 1915.
9. Soils of Fiji—I, 1916.
11. Alluvial Soils of Fiji, 1919.
12. Leaf Moth of Coconuts, 1919.
13. Sea Island Cotton, 1920.
14. Transparent Coconut Scale, 1921.
15. Purple Leaf Moth of Coconuts, 1924.
18. Control of Coconut Spike Moth, 1935.

The following are available to the public at the prices shown—

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23. Insect Pests in Fiji, 1946. Price 1s.
Gardening Notes, Insect Pest Control and Plant Diseases, 1945. Price 1s.
24. The Botanical Gardens, Suva, 1948. Price 1s. 6d.
25. Observation on Copra Drying and Copra Dryers, 1950. Price 1s. 6d.

Applications should be made to the Librarian, Department of Agriculture, Suva, Fiji.

—Editor

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ISSUED BY THE DEPARTMENT OF AGRICULTURE, FIJI.

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EDITORIAL . . .

THE YEAR 1953

The year 1953 in Fiji has been a remarkable one which will no doubt be long remembered and quoted in the annals of the Colony. The Coronation of Her Majesty Queen Elizabeth II in May, and the Royal visit in December, were events the magnitude and benefits of which have yet to be fully appreciated. In one or more humble ways the Department gladly shared with other loyal citizens the additional duties associated with the celebration of these Imperial occasions.

In spite of drought and earthquake, for farmers and planters the year was in several ways a record one and for the Department an unusually busy and interesting one. For the primary producer, overseas markets were most favourable: copra reached the record price of £65 per ton (f.o.b. Suva); banana prices were increased to 20s. per case and an all time record export of 383,000 cases attained. In September Dr. R. W. Harman, General Manager, Colonial Sugar Refining Company Limited reported a magnificent crop of sugar cane, nearly 1,500,000 tons of cane calculated to yield in excess of 180,000 tons of sugar. This large expansion of planting in Fiji, coupled with a good growing season had resulted in a record crop—sales of raw sugar alone would bring in about £6,000,000 over £1,000,000 more than the previous year.

During 1952 the purchases of copra in the group had totalled 40,096 tons of a value of £2,359,506, the highest on record. The figures for 1953 are 33,040 tons, valued at £2,165,922.

For the Department of Agriculture, several major advances were achieved in the provision of both facilities and staff. At Suva the new laboratory for Botanical investigations was completed, at Koronivia the Farm Institute buildings, the new labour quarters were erected and a start made with the central biological laboratories At Sigatoka significant advances with farm development were recorded. At Naduruloulou the Plant Introduction and Quarantine Station made progress with installations and with propagation work including the vegetative propagation of Cocoa. In the field of land development and production many valuable projects, undertaken in collaboration with other institutions and with the farming public, reached a high level.

In the matter of personnel, gains were made by the appointment of the Plant Pathologist, the Biochemist and the Botanist under the Colonial Development and Welfare scheme; the Marketing Officer assumed duty towards the end of the year. Losses were, however, heavy, including the transfer of the Deputy Director of and two Agricultural Officers. Absent on leave for the greater part of the year were no fewer than seven senior officers.

Increasing responsibilities especially those associated with the new problems associated with the rhinoceros beetle and citrus canker eradication campaigns, as well as those arising from the revised plan for economic development have had to be met, and may collectively be advanced as among the reasons for the late appearance of this number of the *Agricultural Journal*.

During the coming year the Department completes 50 years of work devoted to the never simple but ever pressing needs of the Colony's agricultural effort.

Editor.

AGRONOMY . . .

FIJI RICE CROP, 1952-53

Each year the officers of the Field Division of the Department carry out a survey of rice plantings throughout the Colony, and by courtesy of the Chief Manager, Colonial Sugar Refining Company, whose officers record rice planted by cane growers, the combined statistics provide a useful insight into the annual production of this valuable food crop. Details of varieties and areas grown by the different races in the Colony, the methods of planting and the estimated yields are given in the reports which are here summarized by J. D. Dorrity. Ed.

SOUTHERN DIVISION.

The Agricultural Assistant Southern (U. Koroi) reports an increase of 518·95 acres over the previous season. This season's increase is represented by an increase from Indian farmers of 193·2 acres and an increase by Fijian farmers of 274·65 acres. About 100 acres of new land has been opened up for rice planting, the new areas being in the districts of Bau, Nakelo, Verata, and Sawakasa in Tailevu and the districts of Lomaivuna and Matailobau in Naitasiri, Rewa and Noco in Rewa, Tavuki and Naceva in Kadavu and in the Navua area. 6,138 ℔ of seed padi was distributed from Naduruloulou throughout the Southern Division.

NORTHERN DIVISION.

The Agricultural Assistant Northern (Mr. S. Bharat) in the absence of the Agricultural Officer Northern, in his report on the Northern Division Rice Survey for 1952/53 season states that there is an increase of 1,141·2 acres over last season's figures. This is due mainly to increased planting by Indian cane farmers—926·0 acres; the remaining 215·2 acres being planted by Fijian farmers. This is the highest recorded planting of padi for the Northern Division.

The Districts of Macuata and Sasa have decreased, giving a lower provincial total than last year. This does not take into account the increased area grown by cane farmers. In the Labasa District the increased cane area has not decreased the area under rice, for new settlements have been opened and both rice and cane planted in them.

Both Cakaudrove and Bua provinces show increased plantings of padi, 113·6 acres in Cakaudrove and 284·8 acres in Bua. The increased areas in Bua are almost entirely due to an increase in area planted by Fijians (46 acres 1951/52: 268 acres 1952/53). The increase in Fijian plantings in Cakaudrove means that three times as much rice is grown by Fijians than ever before.

This is a record rice year in the division; the previous best was 8,363 acres in 1948/49. The position is not quite satisfactory as the increase is largely due to cane farmers. If the price remains good Fijians planters will be further encouraged, but their contribution may vary from year to year.

The erection of a second rice mill at Bua and the purchasing of milled rice at 10d. per ℔ at the rice mills last year has had a very stimulating effect and resulted in the increased planting of padi.

1953 Season—

46 per cent of the crop was broadcast.

47 per cent of the crop was transplanted.

7 per cent of the crop was drilled.

Figures are not available for 1951/52 as C.S.R. returns are incomplete but 1950/51 figures are:—

25 per cent broadcast

66 per cent transplanted

9 per cent drilled.

Transplanting is still favoured in Bua and Cakaudrove, but the large bulk of the cane growers rice crop was broadcast as the method used in preparing land for transplanting padi is considered not beneficial to the following cane crop.

Records to the nearest acre for the past five years are given below:—

1948/49	8,363
1949/50	8,017
1950/51	7,141
1951/52	8,315
1952/53	9,455

Ram Cajara is the most popular variety grown and has almost doubled its area which is 4065·6 acres. New Guinea has been beaten by Motka this season. Motka is liked by the farmers for its late planting and maturing qualities and high milling percentage. When work with other varities is over, plantings of Motka is continued till late in February and harvested in July. If the incidence of "Rice Yellows and Hoppers" could be controlled I believe Motka would again take the lead.

The following table shows the six most popular varieties this year, and also how they fared in the previous five seasons:—

	1952/53	1951/52	1950/51
	acres	acres	acres
Ram Cajara	4,066 1st	2,301 1st	2,599 1st
Motka ..	1,692 2nd	1,458 3rd	982 3rd
New Guinea	1,679 3rd	1,638 2nd	1,929 2nd
Karia ..	317 4th	....	....
Patna ..	316 5th	419 5th	314 5th
China Patna	312 6th	406 6th	359 4th

	1949/50	1948/49
Ram Cajara .	2,156 2nd	1,332 2nd
Motka ..	1,122 3rd	1,071 3rd
New Guinea	2,160 1st	3,035 1st
Patna ..	861 4th	617 4th
China Patna	321 7th	474 6th

It is estimated that the average yield will be about 10 bags per acre = 30 bushels per acre.

WESTERN DIVISION.

The Agricultural Officer Western (Mr. A. D. Mercer) in his report for the 1952/53 season states that rice planting records were obtained this year from seven representative settlements, from Sigatoka to Raki Raki. A comparison with the figures for last year rather confirms the impression that rice acreage is declining in areas of extended cane planting, but shows an increase outside the cane areas.

Settlement	1952 Acreage	1953 Acreage	Difference Acres	per cent
Korovutu, Nadi ..	89	73	−16	−18
Votualevu, Nadi ..	489	402	− 87	−17
Saru, Lautoka ..	373	226	−147	−39
Drasa, Lautoka ..	126	80	− 46	−36
Qaitoka, Ra ..	23	25	+ 2	+ 9
Tabataba, Ba ..	202	272	+ 70	+35
Bilalevu, Sigatoka..	41	76	+ 35	+85

Figures of production by cane growers, provided by the courtesy of the Chief Manager, C.S.R. Company, show an increased acreage over last year, but this is due to the enlargement of a number of cane sectors and the consequent inclusion of settlements not previously recorded by Company officers.

On the whole the total area planted throughout the division is probably little changed from last year. The supply of rice should, however, be improved as the season has been favourable and yields of the later crops will be above those of last season.

A summary below of the varieties planted in the seven settlements shows Bandala as still the most popular variety.

Variety	Transplanted	Drilled	Broadcast	Total
Bandala ..	48·8	13·8	170·1	232·7
Mutmuria ..	15·0	20·2	187·0	222·2
Patarka ..	162·6	15·7	11·0	189·3
China Patna .	89·7	18·0	18·5	126·2
Saraya ..	4·0	47·0	39·9	90·9
Ram Bhog ..	34·0	9·2	15·5	58·7
New Guinea .	28·4	21·0	5·0	54·4
Sonacalif ..	3·5	16·7	1·5	21·7
Karia.. ..	10·5	1·7	·6	12·8
B.G. 75 ..	9·5	....	....	9·5
Ram Cajara ..	5·0	....	2·5	7·5
	411·0	163·3	451·6	1,025·9

A small number of Fijians in Ra Province continue to plant rice, but elsewhere there is a marked falling off. This can most likely be attributed to high prices for other produce.

MAIN VARIETIES OF RICE: NORTHERN DIVISION IN DISTRICTS: SOUTHERN DIVISION IN PROVINCES: WESTERN DIVISION ALL OVER TOTALS.

	Motka	China Patna	New Guinea	Ram Cajara	Bandala	Serea	Sona-Calif	Patarka	Mut-muria	Karia	B.G. 75	B.G. 79
Macuata—												
Sasa	107·8	8·0	153·0	442·4	....	....	1·5	....	....	....	....	....
Labasa	110·8	28·8	427·7	732·1	....	....	7·5	....	....	10·0	....	....
Macuata	283·0	108·5	116·2	809·8	....	....	6·5	....	....	3·0	....	....
Dogotuki . ..	....	....	12·0	37·0	....	....	....	....	....	....	....	....
Bua—												
Wainunu	·2	....	7·2	17·2	....	....	....	....	....	....	....	....
Vuya	21·0	14·5	30·7	158·5	....	....	....	....	1·0	....	....	....
Bua	216·9	140·0	198·7	414·6	....	25·5	25·5	....	....	1·5	....	....
Cakaudrove—												
Vaturova . ..	11·6	....	126·3	184·0	....	·3	7·6	....	1·0	23·4	....	....
Savusavu . ..	9·5	·5	54·8	36·5	....	2·0	....	....	....	2·0	....	1·5
Wailevu	3;0	12·0	4·0	23·5	....	....	10·5	....	....	....	....	....
Tunuloa	6·0	....	16·5	....	....	....	....	....	....	....	....	....
Cakaudrove ..	2·5	....	11·0	....	....	....	4·0	....	....	3·5	....	....
Southern Division Provinces—												
Tailevu	4·3	282·1	820·9	414·6	117·4	91·2	29·0	18·1	....	12·0	6·5	11·0
Rewa	4·4	213·2	24·0	89·6	....	....	....	....	....	....	....	....
Naitasiri	1·0	229·9	134·7	198·6	2·5	19·0	6·4	6·5	....	1·5	23·5	4·9
Serua	1·0	50·5	426·9	47·2	....	2·5	·5	....	....	....	3·0	....
Kadavu	....	1·3	12·0	9·5	....	....	....	....	....	....	....	....
Namosi	....	100·5	758·2	26·0	....	11·6	5·0	....	....	....	....	....
Lomaiviti . ..	....	....	....	11·3	2·3	4·0	....	1·0	....	....	5·3	3·8
Western Division Province—												
Ra . .. / Ba . .. / Nadroga and Navosa	....	2181·0	1058·0	950·0	3939·0	....	275·0	3095·0	228·0	150·0	50·0	50·0

	Transplanted			Drilled			Broadcast			Total planted	No. of Growers
	Indian	Fijian	Others	Indian	Fijian	Others	Indian	Fijian	Others	All Races	
	(Acres)	(Acres)	(Acres)	(Acres)	(Acres)	(Acres)	(Acres)	(Acres)	(Acres)	(Acres)	
Southern Division—											
Cane Growers	3152	....	....	....	....	....	188	....	....	3340	1,228
Others	2955·4	437·5	24·7	323·9	111·3	132·2	75·1	....	....	4060·1	
	6107·4	437·5	24·7	323·9	111·3	132·2	263·1	....	....	7400·1	1,228
Western Division—											
Cane Growers	9146·6	282·1	6·5	2146·5	109·4	5·5	6904·3	171·1	3·0	14733·0	.....
Others	....	....	....	....	....	....	....	....	....	4042·0	
	9146·6	282·1	6·5	2146·5	109·4	5·5	6904·3	171·1	3·0	18775·0	.....
Northern Division—											
Cane Growers	4102·8	218·8	110·0	670·5	....	2·0	4168·3	179·4	4·0	3728·0	1,350
Others	....	....	....	....	....	....	....	....	....	5737·8	
Total	4102·8	218·8	110·0	670·5	....	2·0	4168·3	179·4	4·0	9465·8	1,350

Southern Division comprises:

Tailevu
Rewa
Naitasiri
Serua
Kadavu
Namosi
Lomaiviti.

Western Division:

Ra
Ba
Nadroga and Navosa

Northern Division

Macuata
Bua
Cakaudrove

Figures for Fiji for the past five rice seasons are:

1953 .. 35,640
1952 .. 35,235
1951 .. 33,919
1950 .. 36,507
1949 .. 36,698

SOIL FERTILITY

(A NOTE)

Decreasing crop yields are becoming of grave concern both to the government and the people of this Colony. It has become a common practice among the peasant farmers in Fiji either to increase area of planting, or look for additional lands as the out put from the farm does not suffice to meet the family requirements. This increased planting with poor returns, involves a great deal of labour in preparing the land, and in producing the crop, as well as a step against the economical use of land

The farmer, although knowing that the main factor leading to this decline in the crop yield is due mainly to the lack of fertility in the soil, does not take prompt steps to remedy it. Increased fertility in the soil not only would yield heavily but reduce the labour very much as well.

One must not forget that most of the plant food elements are found in the top soil only, which is within a depth varying from one inch to one foot according to the place, This is the depth in which most of the plant roots roam freely about and draw the required food and feed the plant. One of the most important points leading to such a decline in the crop yield is the planting of crops year after year without returning to the farm its requirements. The earth provides man with his requirements. Man in return must provide the earth with plant food elements in sufficient quantity so that the plant roots can freely draw sufficient food and produce heavy yields.

One of the simplest but most effective methods to do this would be to feed the earth with humus. Humus is merely a term referred to all easily decomposed soil offerings such as cattle dung, grass, leaves and litter in a state of decomposition.

The process of making compost is quite simple. Drive four thin posts at a distance, depending on the size of the bulk one wishes to make. A suitable size would be six feet by six feet. Heap dry grass, peanut residue, pulse pods, cattle dung and any other soft materials to a height of one foot or so and then a layer of soil. Press the whole matter down thoroughly. Provide another layer of grass and then another layer of earth. Repeat this until the bulk reaches a height of 5 to 6 feet. The bulk should be finished off with six inches of soil over it, pressing the bulk each time as it is made.

Turning the bulk will be necessary from six to eight weeks. In the wet season the decomposition will be faster while it will take a longer period in the dry season. The bulk should be kept moist in order to get quick results. If the conditions for the changes in the process are favourable, the manure should be ready for use in about three months.

The manure thus prepared contains all the plant food elements and moreover carries multitudes of tiny but beneficial soil bacteria. These draw nitrogen from the air and change it into nitrate, the form the plant roots readily take in, and make conditions favourable in the ground as well as building up stem and leaf growth. Poultry droppings being an excellent manure can also be added to the compost. Cattle dung exposed in the sun looses a great deal of manurial value. A combination of both animal droppings and plant matter should provide excellent manure, which if added regularly to the soil will improve the quality and texture, hold the moisture and regulate temperature.

A remarkable crop yield was recorded by the members of the School Farm Club at Veisaru, Ba. Two cuttings of tapioca were planted in each hole one without any manure added while the other hole was treated with compost manure. All plants harvested at the age of 39 weeks In the hill without any manure, plants with single stem about two feet high produced about three pounds of roots, while in the hill treated with manure the plants were well branched out up to six feet high, produced 50 pounds of roots. From this one can easily gather what an important part compost manure can play in increasing the crop yield.

Another important means to maintain the fertility of the soil is the use of green manure crops such as, cowpea or Mauritius bean. In order to get the best results from these crops, the plants should be ploughed at a time when the flowers are just commencing to open. This is the period the plants carry the highest content of nitrogen.

In the cane areas the practice of clean burning the trash should be varied. There are two ways by which this can be done. (1) By allowing the trash after the plant crop is harvested to dry thoroughly and then harrow cross-ways with the harrow upside down, so that the trash will be broken down to pieces and then plough in between the furrows. In the case of farms with heavy trash where this is not possible then the trash can be burned at a very early stage when the top layer is just dry. Fire should be set from the windward side so that the fire will travel at a fast rate burning the top layer only, leaving a fine layer of unburnt trash which can be easily ploughed in. Both these methods will provide the earth with sufficient plant food when the decomposition takes place in the soil.

MUTU SAMI.

SIGATOKA POTATO CROP, 1953

BY A. D. MERCER

Potato growing became well established in Fiji during the war years as a result of the need to supply some of the requirements of the armed forces in the Colony, and has continued since then with varying success. During 1953, *an attempt was made to record details of the crops grown and to observe the methods employed and results achieved by the growers.*

The commercial production of potatoes is confined almost entirely to the flats of the Sigatoka river valley, where the main soil type is a clay loam. The growing period is during the cool season, from May to September, when the rainfall is usually adequate at about 15 inches and temperatures range from 65°–80°F. Rainfall is usually well distributed over the season, but in exceptional years extremes of wet or dry conditions may be experienced.

Seed of the varieties Factor, Sebago, Bismarck, Sequoia, Brownell, is usually obtained from Australia; but difficulty is encountered in procuring supplies at the required time. Planting should commence in May and be completed by the end of June, but late delivery of seed has been responsible for delay until July and even August. Most growers will purchase certified seed if available, but generally have little choice in the matter, and are compelled to take whatever seed is offering*. Growers are mainly Indian smallholders but some Fijians also plant small areas. The total crop is 1952 was 250 acres, with an average yield of 4½ tons per acre. This acreage, though small, is sufficient to meet local market requirements for the short period the potatoes are on sale, as they will not keep for more than a month or two.

The 1953 season opened with warnings of the possibility of no seed potatoes being available from Australia, which led to enquiries being made in New Zealand, where seed was also extremely short, and where only early varieties would be available in time for planting in Fiji. Finally eight tons of certified *Epicure* and *Arran Banner* were secured from New Zealand, 28 tons of *Sequoia*, *Factor*, *Sebago* and *Bismarck* from Australia, together with quantity of un-named, uncertified varieties sufficient for a total planting of 130 acres, or about half the acreage of the previous year.

Planting commenced with the arrival of the first seed in May and continued, as later deliveries arrived into July. It was found that most growers spread their seed on the floor of a shed and covered it with sacks, instead of exposing the seed to moderate light to encourage strong shoot development. All growers cut their seed for planting, in most cases the sets being far too small; and the result was seen in long gaps in the rows of growing plants where seed had failed. The average planting rate was 5·6 cwt. per acre. In many cases planting is carried out with horse or bullock-drawn ploughs, but this year the use of Co-operative Society tractors allowed the employment of ridgers by some farmers. The standard of inter-row cultivation and moulding-up was generally good; but the initial ploughing and cultivation before planting was not deep enough.

Wilt disease developed in many crops at an early stage, in varying degrees of severity; but no connexion could be traced between the incidence of disease, and factors such as quality of seed, variety or previous cropping, except that crops on newly-cleared land were least affected. The earlier plantings, mainly of *Epicure*, *Arran Banner* and un-named, uncertified seed made reasonable growth, but yields were affected by dry conditions in the later stage of growth. July plantings were severely affected by drought, and yields were very poor, averaging 2¼ tons per acre. Instead of the normal 15 inches of rain during the growth period May to September, rainfall in the 1953 season was light, and drying winds prevailed over long periods.

* In 1947 the Department arranged for the supply of certified seed (disease free) from Australia and prohibited the importation of other seed.(1)

Rainfall 1953

	Inches.
May	·55
June	3·62
July	2·88
August	nil
September	1·50
	8·55

The heaviest yield, of 10 tons per acre, was secured from a crop of *Epicure* planted in June on new land at Qalimare, the seed rate of 7 cwt. per acre being above the average. Owing to the small acreage planted and the poor yields, prices remained high at £50 per ton throughout the season.

The crop recordings are summarized in the following table.

SIGATOKA POTATO CROPS: 1953.

Variety	No. of growers	Area Planted	Weight of seed per acre	Incidence of wilt: Nil	Slight	Heavy	Average yield per acre		Total Yield	
		acres	cwts.				tons	cwts.	tons	cwts.
Certified—										
Epicure	14	11·5	6	6	4	4	1	12	30	
Arran Banner	9	6·3	5·3	6	2	1	3	9	21	15
Sequoia	11	40·0	6·5	1	7	3	1	0	40	6
Factor	5	9·0	5	2	2	1	1	16	16	5
Sebago	2	·8	5·3	.	2	.	4	0	3	5
Uncertified—										
Factor	3	2·7	6	.	2	1	2	0	5	6
Bismarck	9	15·0	4·3	2	5	2	2	15	41	10
Unnamed	28	25·0	6·4	7	12	9	2	14	67	0
All varieties	81	110·3	5·6	24	36	21	2	8	225	7

The Sigatoka potato crop, small as it is in area, assumes considerable importance to the Colony in view of the uncertainty of supply from former sources of imports; and the area now cropped is capable of considerable expansion if supplies of seed can be assured. Growing is in the hands of peasant farmers lacking experience in potato cultivation, and though this lack of knowledge is being remedied by a system of trial and error, observations this season point to the need for Departmental staff to direct the attention of farmers particularly to the following points.

1. The need for deeper ploughing and cultivation.

2. Selection of good seed and early planting. Though sound advice, these are factors normally beyond the control of the grower under local conditions.

3. Sprouting of seed before planting.

4. The false economy of cutting seed too small.

5. The extreme danger of heavy loss from wilt unless the crop is widely spaced in a rotation.

6. The need for careful trial and observation to determine the most suitable, under local conditions, of the varieties available for—

(*a*) the highest yields;

(*b*) resistance to wilt;

(*c*) keeping qualities in the tropics.

REFERENCE.

(1) Parham, B. E.—Importation of Seed Potatoes, Agric. Jour., Fiji, Vol. 18, No. 4, 99.

AGRONOMICAL INVESTIGATIONS, 1953

PROGRESS NOTES FROM THE AGRICULTURAL STATIONS

By R. R. MASON

These notes, it must be emphasised, refer to experiments in progress on the Principal Agricultural Station, Koronivia, and the Agricultural Station, Sigatoka; final reports and the conclusions to be drawn from them are published on completion of each series of experiments.

RICE

In collaboration with the plant introduction programme of the South Pacific Commission and by courtesy of the Executive Officer for Economic Development (Dr. H. G. McMillan).

Varieties.—Small samples of 18 varieties were introduced from U.S.A. and five from Malaya. The American varieties appear quite unsuited to Fiji conditions but three of the Malayan ones were very promising, and two appear to be stronger in the straw than local varieties. These Malayan varieties have been planted in a trial at Koronivia with the comparable Fiji variety *Motka* in the present season. Three of the introductions from British Guiana have now been under trial for two seasons but show no advantage over the established *BG* 75 and *BG* 79. Selections made in the variety *New Guinea* in 1952 were grown; and six of the best lines have been planted in a replicated trial on both dry and wet land this year. A trial has been laid down at Sigatoka on local dry-land varieties.

Methods of Planting.—A trial was laid down to find the differences resulting from planting different numbers of seedlings per "hill" or clump. The first year's result indicates that three or four seedlings are better than one, but as good as six or eight. The trial is being repeated this year. New trials this year include one to determine the optimum age of seedling for transplanting, and another to show the effect of planting at different times of the year. Trials at both stations on seed rate and row width of drilled rice will complete the series of such experiments.

Fertilizers.—Sulphate of Ammonia as a top-dressing on dry land rice has given consistent results at Koronivia. The first of a series of trials to show the best stage at which to apply the top-dressing gave no difference between 2, 6 and 12 weeks, but gave increasing responses to increasing amounts up to 4 cwt. per acre. This is being repeated this year, together with other new trials. Exhaustion trials on both wet and dry land will show how long rice, with or without fertilizers, can be grown on the same land. A series of simple fertilizer trials on the two stations and also on Indian farmers' land in Navua and in the Western district has been commenced. These are designed to show the maximum response obtainable from artificial fertilizers and lime, and the response from sulphate of ammonia and lime.

BANANAS

At both stations the effects of three different treatments, clean cultivation, grass cover, and legume cover are being tested. The effects of liming are also being tested at Sigatoka and of a complete NPK manurial mixture at Koronivia. The latter is showing up very strongly but as yet there are few differences between the other treatments. Another trial at Koronivia was laid down to investigate the effects of planting at the (normal) distance of 11 feet by 11 feet as compared with those of closer planting.

SUGAR CANE

At Koronivia an experiment is being carried out in co-operation with the Colonial Sugar Refining Company Ltd. to investigate the effects of five different rotations. These are:—

- Cane, Ratoon Cane, Green Manure (3 years)
- Cane, Ratoon Cane, Rice (3 years)
- Cane, Ratoon Cane, Rice, Green Manure (4 years)
- Cane, Ratoon Cane, Tapioca, Rice, Kumala, Green Manure (5 years)
- Cane, Ratoon Cane, Grass Ley (5 years)

This experiment is now entering its fourth year.

CROP ROTATIONS

Four different crop rotations are being compared. One is continuous arable cropping and the others contain grass leys of 2, 3 or 6 years.

MACHINERY

At P.A.S. a 1951 model 6-h.p. " Gem " Rotary Hoe with large diameter wheels for working in wet padi fields has been tried out in two seasons. The action of the hoe gives a soft mud very suitable for transplanting padi. Since the rear skid leaves an uneven surface, a roller was made and fitted locally. Rollers can be obtained from the manufacturers. Faults in the design which have been rectified locally were weak wheel spokes, which broke, and lack of sealing against mud of the final chain drives. The depth adjustor has also given considerable trouble. The magneto is in a very exposed position and is liable to get wet if working in water. The large-diameter wheels are suitable for work on firm ground but sink in soft areas. The range of gears gives a good selection for different conditions, but rate of work with a 20-inch hoe is slow on soft ground.

A small " Lennon " wheat stripper was tried on rice. The machine has no cutter-bar but relies on the action of a rapidly revolving beater which strips the standing grain fed in by long fingers, leaving the threshed stalks. This " threshing Drum " is driven by a small petrol engine. The frame is on three wheels for horse draught and the fingers and drive can be raised or lowered to suit the height of the crop. Although some success was reported from the drier western division, the machine was of little use at Koronivia for rice, although later in the year it proved very good for harvesting grass seed. The differences between the wheat and rice plants account for much of its failure—in particular, the rice leaves which are still green when the grain is ripe continually choke the fingers. The lack of a clutch between the engine and the drum was a considerable hindrance in clearing the fingers. (Plate 1).

Plate 1.—Ferguson tractor and miniature rice harvester working in heavy crop, 1953.

CHEMISTRY . . .

NOTES ON PLANT NUTRIENTS IN SOILS

BY A. R. BROWNING

Many workers, some with little experience in the tropics, maintain that work on temperate zone soils and agriculture cannot be applied holus-bolus in the tropics, and while in some ways this is true, the problems of tropical agriculture are in the broadest sense the same as those of the temperate zones. The fundamental problems are naturally the same the world over; the soil must be kept permeable to water and air, erosion must be controlled and drought combated, and the nutrient status of the soil must be kept reasonably high. (*Russell*[1]).

The following notes are concerned with the plant nutrients in soil; what they are, the various forms in which they occur, and their availability to plants; and with methods of estimating them and of correcting deficiencies. They are based on work carried out in temperate zones because at present there is little other basis for consideration of these things in the tropics. Before there can be a branch of agriculture which might be called "plant nutrition in the tropics" great numbers of soil and plant analyses must be accumulated and these must be connected with and capable of interpretation in terms of crop yields. Be this as it may, much of the knowledge gained from temperate zone agriculture can be, and is being applied to tropical agriculture at present, and in the planning of experimental work which will eventually help to increase production from the land in tropical countries.

Water.—Water has been said to be the principal plant nutrient. Whether it is a plant nutrient in the common sense of the term is debatable. It is, however, one of the chemical substances without which there would be no life as we know it, and it is a factor which must frequently limit plant growth on the western sides of these islands in the dry season. Its functions are numerous. The principal ones so far as plant nutrition and soil fertility are concerned, are briefly:—

(*a*) It is one of the principal agencies by which rock is turned into soil by both chemical and physical changes.

(*b*) It is able to dissolve and hold large quantities of plant nutrients in solution.

(*c*) It is used in large qantities in the transfer of nutrients from soil to plant, in translocating chemical substances within the plant, and in building components of the plant itself.

Most plants contain some 60% or more of water, and bananas for instance, transpire some 600 pounds of water in the production of each pound of dry matter. Some idea of the amounts involved may be gained from considering a banana crop producing say 20 tons of total vegetable matter per acre. The standing crop would contain some 16 tons of water and produce some 4 tons of dry matter (weight of material after removing water at about 100 degrees centigrade). In the production of this 4 tons of dry matter some 2,500 tons of water will have been taken up by the plant roots and transpired as water vapour.

Calcium, Liming and pH.—Calcium is present in all soils and except in rare cases is in sufficient amount to provide plants with all they need for normal growth. Except when the amount is very low, it is always in an available form. Nevertheless, many soils need the addition of lime, not to supply plants with calcium but to raise the soil pH—that is, to make the soil less acid.

Soil particles have exchange positions on them and basic ions are attracted to and held at these points. These exchange positions are occupied in the main by hydrogen, calcium, magnesium, potassium, sodium and ammonium ions. It is possible to measure in the laboratory the number of positions there are in soil, and the relative

amounts of hydrogen and other ions which occupy them. If a soil has a base exchange capacity of say 30 milli-equivalents per cent (can be thought of as thirty exchange positions per 100 grams of soil), and further has bases—calcium, magnesium, potassium, etc., —occupying 10 of them, this soil is said to be 33% base saturated. In the main the other 20 positions will be occupied by hydrogen ions. If lime is added to this soil calcium ions will replace some or all of the hydrogen depending on the amount added. Should sufficient lime be added to increase the number of exchange positions occupied by calcium and the other bases to 20, the soil will now be 66% saturated. The hydrogen which has been displaced will eventually be neutralised and removed in percolating water. Since hydrogen is the cause of what is called acidity, removal of it will decrease the acidity of the soil, that is, raise the pH. Because the pH of a soil and its percentage base saturation are connected in this way, it is possible to raise the pH of a soil by adding calcium and other bases such as magnesium, or to lower it by removing them using ammonium sulphate, sulphur and other acid, or acid producing substances.

Opinions are divided as to whether the advantage gained from liming acid soils lies in raising the pH, or in increasing the percentage base saturation. In the normal course of events it is a moot point, since in most cases one implies and is accompanied by the other. (There are exceptions, as when gypsum is added to saline soils). The practical point as far as agriculture on non-saline soils is concerned is that most plants seem to thrive best when, other things being equal, the soil has a pH about 6—or, and it is usually another way of saying the same thing, when its percentage base saturation is between about 60 and 80. Theoretically a soil of pH 7 should be about 100 per cent saturated but this is rarely found for reasons which need not be gone into here.

The pH scale is used to express degree of acidity. It ranges from 0 to 14. pH 7 is neutral, that is neither acid nor alkaline, below 7 is acid, above alkaline. Soil pHs range from about 4 in very acid peats to 8 or so in saline soils ; when below 5 soils are said to be very acid ; about 6, moderately acid ; from 6.5 to 7, slightly acid to neutral, while those above 7 are called alkaline.

There is a great deal to be learned about the availability of plant nutrients in soil, but much is understood—sufficient to allow us to predict and explain many of the effects of liming, for instance. It is, as already mentioned, a matter of observation and measurement that most plants grow better in soils with pHs around 6 than they do when the pH is as low as 5, or much greater than 7. It has been shown that plants can usually extract more phosphorus from soils with pHs in the neighbourhood of 6.5 than from more acid or more alkaline soils. Most soils contain relatively large amounts of total phosphorus which is unavailable to plants because it is in the form of iron, aluminium and other compounds which are insoluble in water, particularly at low pHs. As the pH is raised to round 6 to 6.5 however, some of this otherwise unavailable phosphorus becomes more easily available. Furthermore, plants are able to recover more phosphorus from added phosphates in many soils when pHs are between 6 and 7, than at other pHs. Much argument goes on about the forms of fixed phosphorus in soils and about the mode of fixation, but the fact remains that the mere liming of most acid soils will result in increased uptake of phosphorus by plants grown on them. Further, although laboratory determinations of so-called available soil phosphorus are most difficult if not impossible of interpretation, in many cases soils with pHs about 6.5 such as some of those of the Sigatoka Valley, tend to give higher available figures than soils of lower pH.

The pH of a soil also has an effect on the decomposition of organic matter. Russell[2] states that the carbon: nitrogen ratio of soil organic matter is typically higher under acid than under neutral conditions, and that the nitrogen content of humus increases with its degree of oxidation, which in turn increases with the pH of the soil in which it (humus) is being formed.

Truog[3] has set out the relation between soil reaction (pH) and the availability of plant nutrients, as given in the following table:—

	Maximum Availability.	
Nitrogen	pH 6·0 to 8·0	Availablity falls off above and below.
Phosphorus	6·5 7·5	" "
Potassium	6·0 up	" below.
Sulphur	6·0 up	" "
Calcium	7·0 to 8·5	" above and below.
Mangnesium	7·0 to 8·5	" "
Iron	up to 6·0	" above.
Maganese	5·0 to 6·5	" above and below.
Boron	5·0 to 7·0	" "
Copper and Zinc ..	5·0 to 7·0	" "

He points out that although a pH range of 6 to 8 is the most favourable for the maintenance of a satisfactory supply of available nitrogen, for instance, this does not mean that if the reaction of a soil falls within this range a satisfactory supply of available nitrogen is assured. All it means is that so far as reaction is concerned, the conditions are favourable for a satisfactory supply of this element in available form. Also, that a pH below 6 does not necessarily mean that a deficiency will prevail, at say pH 5; it means that so far as reaction is concerned, the conditions are not favourable for an abundant supply in available form. Other factors than reaction may promote the presence of an abundant supply; more-over, certain crops having a low requirement may be satisfied with a low supply.

All the available evidence leads to the conclusion that most plant nutrients are at or near their maximum availability when soil pHs are about 6 to 6.5 It should be noted however, that merely raising the pH of an acid soil by liming cannot increase the availability of any nutrient element which is lacking from the soil, and it will in some cases reduce the availabilty of such elements as iron and manganese if these are already appproaching deficiency level in total amount. This, of course, should not be taken as a reason for not liming but as an indication that the deficient elements must be added also.

Soil pH and lime-requirement can both be determined cheaply and rapidly in the laboratory, and the questions whether to lime a soil or not, and how much lime to apply, should not be matters for speculation and guess work.

The need for continuous application of lime is due to the fact that calcium is removed from soils in crops and animal produce, and through leaching by percolating water. In temperate zones of medium rainfall this annual loss is reckoned to be about 5 or 6 cwt. per acre per year, and the amount is probably not less than this for the drier parts of Fiji with rainfall of some 70 inches and would certainly be more in the wetter areas. An adequate lime regime for acid soils calls for an initial dressing sufficient to raise the pH to about 6 or 6.5 (amounts vary but are frequently between 2 and 5 tons per acre on non-sandy soils in temperate zones), and subsequent replacements every year or two to make good the inevitable losses. Ideally, a finely ground, quickly available form of lime applied in bulk initially, and annually thereafter is best, but practically, it is often better to use rather larger quantities of less readily available, coarser lime such as ten-mesh coral sand of suitable quality in the first instance and to top dress with the same material at longer intervals of perhaps three years. Over-liming must be avoided at all costs. The results in terms of production can be much worse than those caused by failure to apply lime when needed. This is due mainly to making unavailable other nutrients because of the high pH which results. The effects of overliming can be remedied, as mentioned before, but the cost is high.

The best form of lime, chemically, is probably so-called agricultural lime which is simply ground limestone (calcium carbonate). Fiji possess ample supplies of high grade limestone occurring both massive and as coral sand, and crushing any of this material will give a product equal to that available anywhere. Other kinds of lime used for agricultural purposes overseas are burnt lime (calcium oxide), and slaked lime (calcium hydroxide). These

are more costly and except in special cases not usually superior in any way to crushed limestone.

Nitrogen and organic matter.—A generalization frequently heard in regard to nitrogen is that no crop is known which will not respond to applications of this element and it is a matter of observation that this is in fact generally true.

Russell[2] says, "Mineralization of soil nitrogen is the name used for the process by which nitrogen in organic compounds becomes converted into inorganic ammonium and nitrate ions. The transformation can probably only take place through the stages organic nitrogen——ammonia——nitrite——nitrate

and as far as is known these transformations are predominantly brought about in the soil by micro-organisms. The soil microflora typically produce ammonia from organic compounds when they set free more nitrogen from the organic matter on which they are living than they can assimilate into their own protoplasm. Further, ammonia forms their sole important nitrogen excretion product under aerobic conditions, though if the oxygen supply is restricted amines may also be produced".

Lees and Quastel[4] have shown that nitrification of the ammonia produced by the microflora takes place wholly at the soil surfaces— that is, the ammonium ions must be attached to the exchange positions mentioned in the discussion on lime, or otherwise absorbed. Only such ammonia (that is ammonia on the exchange positions) can be converted by the various bacteria to nitrite and finally to nitrate ions in which form plants probably take up most of their nitrogen. (Ammonium ions from ammonium sulphate or other salts applied to soils will also only be oxidised when on exchange positions). A corollary of this is that overliming will reduce nitrate formation by saturating all or most of the exchange positions with calcium ions, and that any quantity of ammonia released by the breakdown of organic matter, or added as ammonium salts, will be lost in drainage water, or to the atmosphere as gaseous ammonia. They have further shown that "the oxidation (of ammonia) only goes on if there is a good supply of calcium and phosphate, and if there is a proper balance of the trace elements iron, copper and zinc."

Generally soil nitrogen is determined in the laboratory as "Total Nitrogen" or as the "available" ammonium and nitrate ions in a water extract of the soil. Both analyses are simple and accurate, but interpretation of results is not so easy as in the case of pH and lime-requirement.

It is generally reckoned that determinations of ammonia- and nitrate-nitrogen, to be of any use, must be carried out on fresh moist samples as taken from the field. Very rapid changes occur in a sample of soil after removing it from the ground and some workers consider it necessary to place samples in copper sulphate or some similar solution within a few minutes of digging to "freeze the equilibrium", if results are to be capable of useful interpretation. Using ammonia- and nitrate-nitrogen determinations, it has been shown in temperate zones that bacterial activity is high in spring, releasing nitrate-nitrogen more rapidly then than at other times of the year ; that seasonal fluctuations generally are quite large and that nitrate concentrations in the soil become very low soon after the addition to the soil of green manures, or other bulky organic matter such as straw, which are low in nitrogen themselves, due to the soil organisms tying up all the available nitrogen in the process of breaking down the added organic matter. When the added organic matter is broken down and attains a carbon : nitrogen ratio of about thirty or below, this nitrogen together with some part of that contained in the green manure is released and again becomes available to plants. Seasonal fluctuations are not likely to be large, if they occur at all, in places like Fiji where temperatures are uniformly high all the year round. Further, where weather conditions (particularly rainfall) are not predictable as in the wet zones, the collecting of sufficient data on nitrate formation in soils, to be of practical use, would be an immense job, and even then it is probable that the overriding factor, as far as supplies available to the plant is concerned, would be the rapid wastage of soluble nitrogen in drainage

water, as it is produced. Any work on nitrate production in soils in Fiji is most likely to be useful on soils of the dry zones where seasonal differences in rainfall and other climatic factors are more marked and vary in a more regular manner than in the wet zones.

"Total Nitrogen" analyses, as the name implies, measures virtually all the combined nitrogen in the soil. Unfortunately the figures give no indication whatever of the amount of this nitrogen which is available to plants, nor do they indicate how rapidly this unknown amount is being made available by microbial breakdown. The only information we get from total nitrogen figures is that one soil has more or less than another. However, figures for total nitrogen do provide data capable of some useful interpretation when combined with those for total "organic" carbon as the carbon : nitrogen ratio. Russell[2] says, "The results of this analysis (C/N) suffer from the limitation that they cannot be directly interpreted, as the carbon compounds present in the soil are very heterogeneous: they vary from plant remains in various stages of decomposition through humified matter to charcoal. Yet such is the lack of appropriate methods for analysing the soil organic matter that the ratio of total carbon to total nitrogen gives as useful characterization of the organic matter in soil as any other method yet in use."

The C/N ratios of many normal agricultural and virgin (that is, supporting "natural" vegetation) soils fall within fairly narrow limits. A ratio between 10 and 12 is common in both cultivated and grassed soils in temperate zones. In general it is reckoned that ratios between about 9 and 12 are normal for cultivated and pasture soils and indicate that decomposition of organic matter by micro-organisms is keeping pace with supply. Figures from 15 to 25 or so are taken to mean that the rate of decomposition is slowing; that is, that soil organisms are unable to decompose the organic matter as fast as it is becoming available. (Forest soils, agricultural soils with low pHs and soils of the wetter, colder parts of temperate zones generally have C/N ratios of this order). If the ratio is 50 or above it is taken to indicate "raw" humus and such material will frequently contain recognizable plant remains and be of a fibrous, peaty nature, with pHs as low as 4.0. Other things being equal, soils with high pHs will tend to produce plants, the remains of which will be readily decomposable, and further, any organic matter will tend to become decomposed more rapidly in these soils than in those of lower pH. Not many figures are available for Fiji soils, but those so far determined include some for the cultivated alluvial soils of the Sigatoka Valley with ratios about 12 and some for the forest soils of the Nadrau Plateau with ratios about 15 to 20.

The amount of organic matter in soils tends to be remarkably constant under any given set of conditions. It is generally higher in virgin soils than in the same or similar soils under cultivation and the equilibrium value once attained is difficult to alter unless the method of using the land is changed. Cultivated soils in Fiji appear to have usually some 1.5 to 3 per cent of total carbon which is equivalent to about 2.5 to 3.5 per cent of organic matter. Similar soils in temperate zones often contain somewhat more than this—about 4 to 5 per cent of total carbon. In an agricultural soil it is difficult to raise the amount or to maintain any increase which might be temporarily achieved. On a soil running say 2,000,000 lb to the 6 inch acre, 20 tons of organic matter like farmyard manure or well rotted compost with a C/N ratio of thirty or less, and containing some 50 per cent of moisture, will raise the level by about one per cent, and the effect will last for a season or perhaps longer. However, cultivation and the high temperatures prevailing in the tropics will provide optimum conditions for oxidization and the operations of soil organisms generally and it is unlikely that the figure will be higher than it was initially within two years of application. This is using organic matter which is well rotted down and has a C/N ratio not far removed from that of normal soil material.

When green crops are ploughed—in the position is quite different. Most non-leguminous vegetation has a C/N ratio of about 100—that is, carbon is greatly in excess of nitrogen. Soil organisms acting on this material reduce the ratio finally to somewhere between 9 and 15 in the normal course

of events, and to accomplish this they will dissipate carbon into the atmosphere as carbon dioxide until this ratio is reached. The result is a loss of much of the substance of the green manure without any material build up of soil organic matter—the final addition of useful soil "humus" being limited by the amount of nitrogen available. Because of this, green-manuring at rates of say 20 tons of fresh non-leguminous matter per acre will only raise the organic matter content of a soil by some one-tenth per cent. The amount may be increased by adding nitrogenous fertilizers with the green crop when it is ploughed in, and by using a legume in the cover crop, but will never exceed that resulting from a similar amount of stable manure or mature compost. An increase of the order of one-tenth of one per cent cannot be measured in the normal course of events because total carbon in apparently uniform soils will vary by as much as 20 to 30 per cent. (Within a few square yards figures often vary between 1.5 and 2.0, and 20 tons of green manure will make a difference of only some 0.1 to 0.2). The position is well summed up by Hamilton[5]. "Bacteria converts organic matter to humus with a C/N ratio of 10 to 12. If organic matter low in nitrogen is dug in, carbon is lost as carbon dioxide until this ratio is obtained. Owing to this relationship between nitrogen and organic carbon, the organic matter in soils under ordinary conditions cannot be increased or even maintained unless nitrogen is also increased or maintained. Hence under the usual system of applying bulky organic material low in nitrogen, the increase of humus obtained is relatively small. It would appear that this is possibly the reason why leguminous crops are preferable to other types for cover crop purposes and have a greater effect in building up the humus supply of soil."

Russell[2] points out ". . . that young green manure will increase the nitrogen content of soils temporarily, but not the total organic matter to any extent, while mature green material will tend to increase the humus content, because it is less readily decomposable, but will not bring about any marked increase in the nitrogen content." He further says ". . . that nitrogen liberated during the decomposition of a green manure crop can only benefit the succeeding crop if the latter is sufficiently developed to take up the nitrogen soon after it is released, and before the nitrate produced is leached from the soil ; and this period is fairly short, particularly in light soils under moist warm conditions. Hence, a long wet period between the ploughing-in of a green manure crop and the establishment of the following crop, particularly in light soils, can result in much of the nitrifiable nitrogen of the green crop being leached out of the soil with the result that the following crop obtains little if any benefit from the green manure. Equally important of course is the fact that crops should not be put in too soon after ploughing-in a green manure, because decomposition of green manures takes up available soil nitrogen and results in a temporary withdrawal of nearly all the soil nitrogen which would otherwise be available to the planted crop."

As can be seen the whole question of soil organic matter and soil nitrogen is very complex. Organic matter itself is not a plant food although when completely mineralized, that is, completely decomposed by micro-organisms, it does supply nitrogen and some calcium, phosphorus, potassium, etc., in forms available to plants. Its principal beneficial effects are in ameliorating the physical properties of soils by increasing water-holding capacity and at the same time facilitating free drainage ; in opening up the soil and allowing more air to penetrate ; in supplying energy to soil organisms (without which there would be no agriculture, as we know it) which in turn help to make inorganic nutrients available to plants in various ways ; in producing substances which bind clays and other fine particles into larger and more stable aggregates and so generally improve soil "tilth", and so on.

Forest soils will usually have more organic matter than others, and some part of this is inevitably lost when the forest is cleared. Grassland soils usually have less than forest soils but more than most plantation-tree-crop and other intensively cultivated soils, some of which are often found to contain less than the equilibrium value which could be maintained under ordinary good land use.

Every effort should be made to conserve organic matter in soils, by controlling erosion which always removes organic-rich top soils, by cover-cropping which at best may sometimes increase organic matter and at worst will help to retard loss, and by adopting wherever possible a system of rotational farming which includes at least two years of of continuous grass every six years. Grassing is without doubt the best practical way of replenishing the organic matter which is always lost under arable farming and the organic matter formed under grass seems to produce more stable soil aggregates, and to resist destruction by soil micro-organisms better than that formed from green manure. The pasture should always contain a legume if this is possible.

The application of any form of nitrogenous matter, whether organic or inorganic, to soils always results finally in nitrate ions appearing in the soils solution, and it is in this form that plants take up most if not all of their nitrogen. (It has been shown that plants can take up other forms of nitrogen, notably ammonium ions and urea, when only these forms are available in experimental work, but it has not been demonstrated that this occurs to any extent in natural conditions). A few days' heavy rain on a moderately well drained soil will remove from the reach of plants any applied nitrates and a good deal of any recently applied ammonium sulphate. Similarly much of the possible benefit of green manuring may be lost.

Ideally, in arable farming, or wherever, intensive cultivation is practised, the aim should be to maintain organic matter at the highest possible level both because it is the most important factor in maintaining desirable physical properties and because it will result in the continuous production of some available nitrogen, and to arrange additions of organic matter and nitrogenous fertilizers at times which will ensure as far as possible that the following crops get the greatest possible benefit. Nitrogenous fertilizers should be applied little and often as far as this is feasible. It is much better to add small amounts at intervals during the life of a plant than to put an equivalent amount on at an early stage and lose some, perhaps a large part of it by leaching. Plants need continuous supplies of most nutrients and although ample supplies are most important when the plant is becoming established, they cannot take up enough from a luxury supply at an early stage of growth to last until maturity is reached.

Phosphates.—Phosphates are like nitrogen compounds in soils in-as-much as it is most unlikely that plants ever manage to recover more than a part of any amounts applied as fertilizer. The reasons are, however, different. Failure of plants to recover all of any applied nitrogen is due to the extreme solubility of nitrates and the consequent leaching by percolating water. Failure to absorb added phosphates is due to the rapid formation of very insoluble compounds of phosphorus in the soil. These compounds are not leached and accumulate in forms unavailable to plants.

The whole question of the forms of phosphate in soils and the mechanisms by which phosphates are rendered unavailable to plants is the subject of more speculation than any other part of soil chemistry. The essential parts of our knowledge seem to be contained in the following.

Phosphates are rendered unavailable to plants by "fixation" as insoluble compounds, the principal of which seem to be iron and aluminium phosphates. There are no known ways of altering soil conditions so that iron and aluminium phosphates can be made available to plants. Plants seem best able to use added phosphates when soil pHs are in the range 6 to 7, and when phosphates are placed, that is sown in bands below or beside plants, rather than broadcast. Pelletted and coarsely ground materials are more often the best forms to use and especially in the tropics, less soluble compounds like reverted super, basic slag and ground rock phosphates will generally be better than the soluble super- and double- (or triple-) phosphates, particularly on pastures.

Most tropical soils are characterised by the fact that in the process of formation, silica is removed from the upper soil zone and this becomes enriched in iron and aluminium compounds. In temperate zones the opposite is true, iron and aluminium being removed from the upper horizons and silica

being concentrated there. This is of particular importance because in the tropics phosphate fixation must be, and is, more vigorous.

Russell[2] says, " In practice, in temperate zone agriculture, the soil is limed before phosphate is applied so the acidity, and hence the concentration of these reactive iron and aluminium ions is reduced. Liming an acid soil often increases the amount of phosphate available (that is native soil phosphate) but this is probably derived from organic matter present, for limng increases its rates of decomposition. On tropical and sub-tropical soils heavy liming is rarely feasible nor is it known if it is desirable, hence the problem of making efficient use of phosphate fertilizers on such soils may have to be solved by other methods. These include the band placement of a phosphate fertilizer near to the plant, possibly preferably as a granular fertilizer, and possibly again as a water insoluble fertilizer such as dicalcium phosphate. They also include the use of superphosphate protected from iron and aluminium ions by mixing it with farmyard manure or compost, and the use of ground rock phosphates, although this may have to be made available to some crops by giving it to a green manure crop which is able to extract phosphate from it, and then ploughing it in."

The manner of analysing soils for available phosphate is not different from many other phases of the chemistry of soil phosphorus. Many methods have been proposed and many are in use. They all suffer from one unfortunate defect—none of the results can be applied generally. Various methods of determining available soil phosphorus do in fact provide useful information about particular soils in particular localities, but comprehensive field experiments and large numbers of soil and plant analyses are needed to establish correlations between soil phosphate as measured in the laboratory and the plants' ability to extract this " available " phosphate, for most combinations of soil type and climate and the particular crop being used. The amount of " available " phosphate in any one soil will vary with the extractant used (citric, sulphuric, nitric, hydrochloric acids, etc.), the concentration of the reagent, the ratio of extractant to soil, the length of time of extracting and the temperature at which it is carried out. When in addition it is remembered that a method which may give useful results in one set of conditions will probably not do so in another, the whole matter is seen to be in an unsatisfactory state at present.

One laboratory method commonly used is to extract it from the soil with 1 per cent citric acid, the phosphate so extracted being considered " available " Using this method on a variety of soils in New Zealand, the writer found no correlaton whatever between the so-called available phosphate and the growth of a number of plants which were commonly suposed to respond to levels of available phosphate in New Zealand. Also, it is generally recognised that 1 per cent citric extracts tend to give high results on peaty soils, but that these figures bear little relation to responses to phosphate on these soils. A particular example is found in the pumice soils of New Zealand which all have relatively high citric soluble phosphate, but on which it is nevertheless quite impracticable to establish pastures unless fairly heavy dressing of some 6 cwt. of superphosphate per acre are applied in the first year, and annual dressings of 3 cwt. or so are continued thereafter.

Recent work by Birch[6] however, seems to indicate that it may be possible to make reasonable predictions about the phosphate status of soils in general—particularly about the likelihood of a response being gained from added phosphates. Using soils obtained from a large number of fertilizer trials on various soil types in Kenya, Uganda and Tanganyika, he has obtained good correlation between the percentage base saturation (see notes on lime) and available soil phosphate. He has shown that, in acid soils, " the degree of base saturation is therefore directly related to phosphate availability, and consequently, inversely related to phosphate response." These results were based on yields of wheat, grass and millet. Phosphate uptake by grass further supported the findings, " Both the percentage phosphate in the grass from control plots and the amount of phosphate taken up by the crop proved to be directly and

significantly related to the percentage saturation of the base exchange complex." The reactions which Birch puts forward to explain the observed facts have been criticized (Wild[7]) but the actual relationships between percentage base saturation, and available phosphate and phosphate responses seem indisputable. Similar relationships have been noted elsewhere but Birch appears to be the first to pursue this aspect of the matter to any length. A point made by Birch himself is that a soil which is deficient in total phosphorous will respond to topdressing even though it may have a high percentage base saturation. The approach seems to be a good one, more likely to be of general application than any others so far proposed, and well worthy of trial in Fiji.

In work on soil phosphates ~~more~~ than with any of the other "major" nutrients, it is through the plant that we must work if we are to understand and be able to apply the results of soil analysis. There is no use in carrying out laboratory determinations of "available" nutrients in soils if plants are unable to obtain adequate supplies from soils which, according to the chemist have ample amounts. Useful work will only be done by combining crop yield data with the results of both soil and plant analyses from properly laid out field trials. Nothing less will suffice.

Before coming to Fiji the writer discussed the problem of phosphates in tropical soils with the then Director of the New Zealand Fertilizer Manufacutrers' Research Association who strongly recommended trial of ground Christmas Island phosphate rock. This is a soft rock phosphate similar to North African phosphate which has been used with success in North Auckland where soils are in many ways similar to those in Fiji. If Christmas Island phosphate should prove satisfactory here it should be possible to arrange for grinding in New Zealand, or possibly in Fiji, at a price which would make it competitive with the phosphates imported at present.

Potassium.—Our knowledge of the chemistry of potassium in soils is less than that of calcium but it is nevertheless considerably greater than our understanding of soil phosphates.

Potassium in soils occurs in three principal forms ; as an integral part of clay and other minerals as such, in a so-called difficultly exchangeable form and as readily exchangeable ions. The first form only becomes available after breakdown of the minerals concerned by soil weathering.

Clay minerals are platy structures and consist of one or more plates lying together. Difficult available potassium is thought to be held between, and in holes in, the surfaces of these plates. Broadly, clay minerals are separated into expanding and nonexpanding types, the former swelling markedly on wetting, the latter not swelling so much. When potassium is added to soils which are then repeatedly wetted and dried, part of the added potassium cannot be recovered immediately by ordinary base exchange methods, but if the soil is left in contact with some cation other than potassium for periods of several months, much of this potassium will be released. Expanding-lattice clays (those which swell on wetting) "fix" potassium more than non-expanding ones, and it is believed that on expansion when wet, the spacings between plates, and the holes on the surface layers become large enough to allow entry of potassium ions. On drying, the lattice contracts and these spacings and holes become too small for the potassium ions to escape again easily. Some soils seem to maintain a constant amount of readily available potassium over long periods when this element is being removed in fairly large quantities by crops. This is probably due to their having a good deal of difficultly exchangeable potassium and an equilibrium is set up between the two forms, which results in a constant amount being in the readily available form in spite of steady removal. Readily exchangeable potassium is attached to the exhange complex (clay and organic colloids) on the exterior exchange positions similar to those which hold exchangeable calcium.

The matter is not simple but nevertheless these conceptions of difficultly and readily exchangeable potassium, and the mechanism of potassium "fixation" are well supported by chemistry and X-ray work on clay minerals, and allow us to make useful predictions based on the analysis of soils. Extensive

work involving field trials and soil and plant analyses are required to establish useful knowledge of the potassium status and requirements of our soils and crops in Fiji, but this has been done in other parts of the world and can be done here, using established methods.

Trace Elements.—These comprise a number of elements which plants need in very small amount only. They include iron, manganese, zinc, copper, boron and molybdenum, and amounts ranging from a few ounces to a few pounds per acre are sufficient to supply plant needs. Russell[2] quotes Piper and Walkley's estimate that a full crop of oats only removes one quarter oz. of copper, one to two oz. of zinc and seven oz. of manganese, compared with seven pounds of phosphorus per acre, but adds that it must be realized that there is no sharp distinction between elements needed in large and small amounts, magnesium and sulphur being two good examples of intermediate elements for many crops.

While the remedying of major nutrient deficiencies usually involves soil treatment, trace elements when needed are frequently applied direct to the plant by spraying, or by inserting pellets under the bark or into holes bored in the trunks of trees. However no strict rules can be laid down and each case must be considered in light of all the conditions. For instance quite severe deficiencies of manganese can occur following over-liming of soils which contain ample supplies of total manganese, and it may be better to make available the manganese already present by adding sulphur to the soil and so lowering the pH, than to spray. When direct application to the soil is preferable the difficulty of spreading as little as a pound or so of material to an acre is overcome by incorporating the trace element with a bulky fertilizer which is normally used. Phosphates are commonly used as carriers and copperised, cobaltised and boronated phosphates are now available overseas.

A few parts per million in the soil is frequently sufficient for plant needs and concentrations the order of 100 parts per million will often be too much, and produce toxic effects. Deficiencies may be natural, due to lack of the particular element in the rock from which the soil was derived, or induced by heavy cropping or over-liming, or both. Likewise toxic concentrations may be due to excessive amounts in parent rocks or to addition of larger amounts than are required. Applications of trace elements must always be thought of in terms of pounds per acre as distinct from the tons in the case of lime, and cwts. for phosphates, nitrogen and potassium.

In all work on the chemical fertility of soils the approach must be made through the plant. It is no use saying that a soil has high available phosphate because we have found in the laboratory that sulphuric acid will extract more phosphorus from it than from some other soil, if plants growing on the one are not able to extract more phosporus from it than from the other. Crop yields and plant uptake are the only criteria against which to measure the value of chemical analyses of soils in fertility work. In fact the chemical analysis of soils, *per se*. has only one advantage over plant analysis and the measuring of crop yields, and that is in the time saved. When working through the plant we can usually get only one set of data a year and large and involved field trials are necessary if we are to gather much information in the course of a growing season. Soil analyses on the other hand can be carried out in a matter of days or weeks. But, whereas we must always get useful information from well laid out field trials by considering the yield and by analysing the plants for nutrient content, more often than not the results of soil analyses are of no immediate value. Figures for total soil nitrogen tell us nothing about the amount of nitrogen a crop can be expected to find available in a soil in the course of a growing season. Analyses of soluble ammonia and nitrate nitrogen in soil can only be of use if carried out at short intervals over a period of years for any given soil growing a limited type of crop and these only when they have been correlated with crop yields and measurements of plant uptake.

In America and some other parts of the world a technique known as tissue testing is used which is on the whole a considerable advance on most other chemical methods in

use. At intervals commencing soon after the crop is established, samples of leaves or stalks are analysed for nitrogen, phosphorus and potash using quick tests which are often carried out in the field and which usually indicate only three levels—high, low or medium. The whole business is quite empirical, but by trial and error over some years it is possible to establish for any crop, levels of the three nutrients which indicate need for addition of fertilizers, during the course of a growing season, if deficiency of one or other of them is not to become a factor limiting that year's crop. In some instances the same sort of thing is done using quick tests on soil, but particularly in the case of the soil analyses, results only apply to the crop on the soil concerned, and are not capable of general use. These quick test techniques are in the meantime used mainly on such crops as corn and vegetables where intensive cropping is carried out particularly for canning. Many large commercial organizations in the United States use tissue testing extensively because they find it pays both in helping to ensure uniformly high yields and in cutting down on fertilizer applications when not needed, but which, without the knowledge gained from these tests, would otherwise have been applied. The method seems to have no application to pastures and large scale cropping but could probably be applied to rice, maize, cane and several other crops in Fiji, and systematic work could not fail to provide useful results in the course of a year or two.

Alone of the soil analyses commonly carried out, pH and lime requirements are in the main capable of useful interpretation without having resort to the plant—and this only because the chemistry involved is simpler, or perhaps better understood, than other parts of soil chemistry. Whatever the case, we can as a result of a laboratory analysis of a soil tell whether or not it is likely to produce a response to liming, and further, within reasonable limits, how much lime should be added to provide a soil reaction best suited to most plants. It is not known whether tropical soils behave in exactly the same way as temperate zone soils when limed, but any difference must in the main be confined to the so-called lateritic soils, and even then will likely be one of degree rather than kind. It seems highly unlikely that any soil with a pH below 5.0 will not benefit from addition of lime sufficient to raise the pH to at least 5.5 or 6.0 It must always be remembered too, that almost any normal soil which has a pH below 5.0 must be highly leached—it would not have such a low pH otherwise—and that its supply of most plant nutrients will be low. Merely liming such a soil will not increase supplies of other elements—these must be added also.

So far as potassium nutrition of crops in Fiji is concerned, we can establish levels of soil potassium which are adequate for good yields for our various crops by carrying out suitable analyses on soils and the crops grown on them and by measuring yields from properly designed experiments, over the course of a few seasons. When however, we come to the question of phosphorus and nitrogen there seems little use in carrying out soil analyses. Perhaps eventually methods will be devised which will enable soil analyses for these elements to be used as pH and lime requirement determinations are now, but this will only result from fundamental work which can probably be done much better in large laboratories, with large staffs and much money and equipment. In Fiji the best we can do about phosphates is to be guided in our choice of fertilizers and our methods of using them, by the knowledge we have of fixation of this element in soils. If we combine this with measurements of yields and phosphate uptake by crops, we will be able to say with reasonable certainty that one or other type of phosphate fertilizer applied in one way or another will result in most efficient use of this element by this or that crop. We may not have learned anything about "soil" phosphate as such, but we shall be no different from most soil and agricultural workers in other parts of the world, and at least we shall to some extent have got on with the practical business of growing more and better crops in so far as we can do so in Fiji. In regard to nitrogen, the writer may perhaps quote the late Professor G. W. Robinson of Bangor, one of England's great soil scientists, who in reply to a question about what was done by the

Advisory Service at Bangor in the matter of nitrogen, said, " What does anyone know about ? We just tell farmers to put it on if they can afford it because we know it will pay for itself if used sensibly."

These notes may appear to over-emphasise the inadequacy of the contribution of soil chemistry to agriculture, but they were written in the hope that they might help those engaged in the practical business of produing from the land to understand something of the problems of the chemistry of soils and plant nutrients as the soils chemist encounters them. All too often in soil chemistry and other parts of agriculture do we see inadequate methods being used to attain ill-defined, nebulous, perhaps non-existent ends. Frank discussion must help us all in our various phases of the job of producing from the land.

The chemistry of soils and plant nutrition has contributed much to the practical business of agriculture in the past and must continue to do so if agriculture is to continue to progress ; but much of the work to date is little known and even when known, not applied. There is much ground to be made in applying knowledge we already have. Our knowledge of the behaviours of soluble phosphates in soils is such that one would expect to find little if any superphosphate used in Fiji, but in fact over the last years most of our phosphate imports have been superphosphate. Furthermore there can be no doubt that coarsely-ground or pelletted forms of phosphate must be more efficient in all but a few cases, such as market gardens, and even this is doubtful, yet most of the super- and other manufactured phosphates imported were finely-ground. Similarly, less soluble forms of nitrogenous fertilizers like urea, nitro-chalk, etc., while they may not produce such rapid nor perhaps such big initial responses cannot fail to be more efficient—to give better returns for money spent.

It is often the case that deficiency of more than one nutrient is limiting plant growth on a soil. Addition of one will not make good the deficiency of the other. There is a tendency to underrate this and talk about lack of response to, say, phosphorus because yields are not increased by topdressing with phosphates. In fact of course the crop is not responding to phosphate, not because it does not need this nutrient, but because another deficiency is preventing use being made of the fertilizer added. Lack of both phosphorus and potassium in soils is not uncommon and although one may have been added, lack of the other is continuing to limit growth. The fact is that with adequate additions of phosphate, a soil will show a response to potassium and conversely, while neither alone will have much effect. Acidity is one of the factors which seems frequently to limit response to added fertilizers, and crops on acid soils will very often not respond to topdressing with other material until lime has been added also.

Some recommendation on types of fertilizer and time and method of application are given below. They are based on temperate zone experience and are necessarily of a general nature. It is not possible to be specific except in relation to a given piece of land and given crops, and then only when due consideration has been given to matters other than soil chemistry.

Liming.—Agricultural lime is cheapest and in most cases as good as any other form. It is probably best used rather coarse in the tropics, particularly in the wetter areas—10 mesh mill-run would probably be suitable, not finer. It should be applied a few weeks before planting for arable crops, although if the amount required is not more than 2 tons per acre it is often best to apply it only one week ahead of planting, as it has been found in temperate zones that emergence of seedlings is often greatly increased if lime is added at, or just before sowing. Amounts needed to bring soils to a desirable pH initially will vary, but once this pH has been attained, replacement dressings of the order of half a ton per acre every two years should maintain it in the drier parts. Rather more will be needed on the eastern sides of the islands. Farmers seeking information should apply to their nearest Agricultural Officer.

Organic Matter.—This is one of the greatest needs of cropped land in the tropics. All forms of organic matter should be conserved and added to the soil. Blood and bone, dried blood, and fish manures are ex-

cellent sources of organic matter and slowly available phosphorus and nitrogen, and although too expensive for use in large scale farming are frequently economic on small holding of high cash-value crops. In large scale farming a crop-pasture rotation is the only feasible way of tackling the organic matter problem. Rotations will vary, but a grass-legume pasture, or alternately a legume green manure crop and two years under grass in every six years is the sort of thing which is necessary if organic matter is to be maintained at a reasonable level.

Nitrogen.—This element is usually added as ammonium sulphate or as a nitrate. The former is preferable because it is less readily leached from the soil. Both however, can be largely washed from the root zone by heavy rain within a few days of application and completely wasted. Less soluble forms such as dried blood, urea, nitrochalk, etc., are less readily lost by leaching and must stand a better chance of being utilized by plants than ammonium salts and nitrates. Nitrogen fertilizers should never be applied to the ground before the crop is sown, unless when turning in a green manure crop. Applications should begin when the crop is sown or planted or preferably a week or so after, and continued as far into the growing season as possible in small dressing every six weeks or so if this is feasible and economic. Amounts used in temperate zones vary but are commonly about 2 or 3 cwt. per acre per year. In general it is not reckoned to be economic to use nitrogenous fertilizers on pastures, but where legumes are poor it may sometimes be worthwhile in establishing grass, and as topdressing in intensive dairy farming to get pastures away early in spring, or to hold them a week or two into the dry period.

Phosphates.—Superphosphate is probably the least suitable form for use in the tropics. When finely ground it can be only very rarely that more than five per cent of the available part of it is recovered by plants. The rest is fixed and lost.

In temperate zones where fixation is less pronounced crops are sometimes able to benefit from phosphates for several years after application. These responses are usually less than in the year of application but may result in perhaps 20 per cent or more of the fertilizer being used in time. Whether the residual effect operates in Fiji soils is not known. If it does it will be to a much smaller extent than in most temperate zone soils.

If for any reason, perhaps because it is the only type procurable, super, or double super phosphate must be used, the pelletted form will provide plants with a great deal more phosphorus than the finely-ground material. Forms more suitable than the common super and double (or triple) phosphates include dicalcium phosphate, reverted super, basic slag, and suitable ground rock phosphates particularly North African and possibly, as mentioned before, Christmas Island rock. The harder apetite-type of rock phosphates such as Nauru Island rock are possibly too insoluble to be of much use when simply ground. For pastures, amounts of from two to six cwt. per acre per year are desirable and should be added in two lots; one just before the end of the wet season so that growth can be held a week or two into the beginning of the dry period, the other just before the end of the dry period so that growth may get away rapidly as soon as the first rains fall. This applies more to the dry parts of the islands of course. There is no lack of growth in the wet season and the aim should be when applying fertilizers, to get the most out of the dry season by closing up the period of lowest production. If a couple of weeks extra growth could be achieved in this way at either end of the dry season, carrying capacities would be increased. In the wet zones the aim should be likewise to close up the period of lowest production.

In cropping, the amounts it will be economic to use will vary, but however much is used three cardinal rules are; sow phosphates in bands beside or below the rows, or around tree crops, never broadcast if it can be avoided; never apply before the crop is sown; and, use coarsely ground or pelletted forms rather than finely ground material. Whenever possible mix phosphate with organic matter as this helps to protect it from reacting with iron and aluminium before plants are able to make use of it.

Potassium.—Older, more strongly leached soils will tend to be low in potassium, as in most other plant nutrients. The form most used as fertilizer is potassium sulphate although the chloride is also used. Sulphate is preferable as there is less risk of damage to crops than with chloride. Insufficient is known about levels of potassium in soils and responses to topdressing in Fiji to allow recommendations to be made, but in temperate zones potassium fertilizers are commonly used in amounts of one half to two cwt. per acre per year and it is not likely that amounts much in excess of this would ever be necessary here.

Trace elements.—No trace element deficiencies have been recorded here but it is most likely that some already exist and that others will develop if the general level of production is raised to any extent by an improvement in farming methods and the use of fertilizers. Such deficiencies should be looked for on calcarious and excessively limed soils, and on poor strongly leached ones. Apart from some of our sugar soils which have pHs of 7.0 and over, we are not likely to find the former except on coral atolls and beaches. However, many of our soils are strongly leached and possible trace element deficiencies should be sought if these soils do not respond to adequate fertilizer applications and proper use otherwise.

Finally, it must not be forgotten that the chemical aspects of soil fertility are only half the story. The ability of a soil to produce good crops and pastures depends as much or more on physical characteristics as on those discussed here. The writer is unable through ignorance to discuss agricultural soil physics, but it is hoped that at some time in the future he or some one else may be able to write some general notes on this part of the subject, for local information of those who have no access to the literature, or perhaps the time to read it if they had.

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THE MAINTENANCE OF SOIL FERTILITY IN FIJI

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The present paper is a contribution to the problem of maintaining the productivity of the land whilst still making use of it in growing food for local consumption or for export. It is easy to preserve soil fertility under any climatic conditions if no crops are grown; the climax vegetation is allowed to develop and the soil and its cover are never disturbed. The land is then useless to man; for even the treading of a permanent track may end this condition of safety. If the land is to be used for food or for any other products of the soil, there enters at once an element of risk that its fertility may be decreased.

Two forms of agricultural land-use in Fiji, which are distinctly different, have been investigated and are reported in this paper. The first is a study of the traditional methods used by the Fijian people in growing subsistence crops. This was carried out in the wet zone of Viti Levu. The second concerns pineapple-growing in the dry zone; in this case most of the crop is canned and exported.

RESULTS OF FIJIAN SUBSISTENCE-CROPPING IN THE WET ZONE.

The location of this investigation was in Tailevu province in the south-eastern part of Viti Levu where rainfall is 120 inches per annum. Only 25 inches falls during the drier period from June to September, but single falls of more than four inches per day may occur at any time of the year.

Three sites were selected within the region, such that at each site there existed, almost side by side, the various stages in the cycle of native shifting-cultivation, i.e. virgin soil, native garden, and land reverting again to bush.

The history of each site was carefully checked through the kind offices of Mr. L. W. Harwood, H.D.A., D.T.A., Senior Agricultural Officer. The enquiries were directed to show that the virgin area had never been cultivated (or at least not for some decades) and also to find out for how long and in what manner the present native garden and its successor—the reverted area—had been under cultivation. This information is presented in Table I. The same table includes a description of the soil and the natural vegetation on the three sites.

TABLE I

HISTORY AND DESCRIPTION OF WET ZONES SITES.

Location.	200 yards on west side of Bau Road opposite village of Ovea.	Environs of village of Navuniasi.	One chain to west of village of Qeledamu.
History.			
Virgin area.	At least 30 years unplanted.	At least 50 years unplanted (and beyond living memory).	About 30 years unplanted.
Cultivated area.	Four years continuous cultivation: yams, then bananas, pineapples and tapioca.	Five years continuous cultivation.	Ten years under cultivation (contoured for one year). Carries pineapples and four year old citrus, etc.
Reverted area.	Eight years resting. Previously cultivated for four years.	Twenty-five years resting. Previously cultivated for six years.	Eight years resting. Previously five years under rice and native crops.
Natural.	Ivi (*Inocarpus edulis*).	Kaudamu (*Myristica castanaefolia*).	Kuluva (*Wormia bifiora*).
Vegetation.	Breadfruit (*Artocarpus incisa*).	Lekutu (*Endospermum macrophyllum*).	Vaivai (*Serianthes* spl.).
	Vutu (*Barringtonia* sp.).	Vava.	Kaudamu (*Myristica castanaefolia*).
	Dawa (*Pometia pinnata*).	Walai (*Entada*).	
	Bamboo.	Tree fern (*Cythea lunulata*).	Lekutu (*Endospermum macrophyllum*).
		Sa (*Parinarium insularum*).	Sa (*Parinarium insularum*).
			Pandanus.
			Bau (*Sapotaceae*).
			Sisisi (*Gironiera celtidifolia*).
**Soil Type.*	Ovea gr. blocky soil (rolling phase).	Waidina y. friable hill soil.	Waidina y. friable hill soil.

* From provisional soil map of Viti Levu by officers of N.Z. Soil Bureau. All sites had a slope of 15 to 25 degrees.

At each site soil samples were taken from the virgin, cultivated, and reverted areas. The soil was sampled by horizons in order to follow any changes which might occur at depth or over any part of the rooting zone. Due to tillage operations the horizons of profiles from the disturbed areas were found, as might be expected, to differ somewhat in depth and colour from those of the virgin profiles.

In Table II are listed the profiles actually examined and the analyses of the soil samples taken from them. The chemical methods used are those of the Queensland Bureau of Sugar Experiment Stations (1), phosphate being determined by a modified Truog method and potash by extraction with 0·02 normal hydrochloric acid.

In this study no specific account has been taken of possible soil erosion as any such effect will be included in the total effect of the land use in question.

TABLE II

SOIL ANALYSES—WET ZONE.

Profile		pH.	Total Nitrogen	Available Phosphate p.p.m.	Available Potash (m.e./100g.)
Ovea—					
Virgin	(0– 6) inches	6·0	0·298	17	0·33
	(6–12) „	7·2	0·143	10	0·21
	(12–48) „	7·7	0·052	28	0·25
Weighted Mean ..		..	0·094	24	0·26
Cultivated	(0–12) „	6·2	0·193	15	0·55
	(12–18) „	6·0	0·041	12	0·50
	(18–48) „	7·2	0·041	18	0·29
Weighted Mean ..		..	0·079	16	0·36
Reverted	(0– 9) „	7·2	0·135	15	0·35
	(9–15) „	7·0	0·082	8	0·31
	(15–48) „	7·2	0·046	20	0·
Weighted Mean ..		..	0·067	18	0·29
Navuniasi—					
Virgin	(0– 6) „	6·0	0·338	28	0·29
	(6–12) „	5·2	0·214	17	0·16
	(12–42) „	5·5	0·014	8	0·16
Weighted Mean ..		..	0·078	12	0·17
Cultivated	(0– 6) „	5·8	0·404	22	1·12
	(6–48) „	5·5	0·048	36	0·17
Weighted Mean ..		..	0·092	34	0·29
Reverted	(0– 6) „	6·2	0·290	20	0·25
	(6–12) „	5·2	0·180	10	0·18
	(12–18) „	5·5	0·138	39	0·16
	(18–48) „	6·2	0·00	18	0·10
Weighted Mean ..		..	0·076	19	0·14.
Qeledamu—					
Virgin	(0– 7) „	4·4	0·388	7·4	0·50
	(7–30) „	4·5	0·066	3·8	0·19
	(30–36) „	4·6	0·025	3·2	0·19
	(36–48) „	4·5	0·031	6·4	0·17
Weighted Mean ..		..	0·108	4·9	0·23
Cultivated	(0– 8) „	4·8	0·244	10·2	0 54
	(8–15) „	4·7	0·142	7·6	0·25
	(15–40) „	5·0	0·054	8·7	0·31
Weighted Mean ..		..	0·107	8·8	0·34
Reverted	(0– 4) „	4·7	0·303	17·4	0·65
	(4–24) „	4·8	0·101	8·8	0·24
	(24–30) „	4·7	0·050	10·1	0·33
	(30–40) „	4·8	0·028	24·8	0·31
Weighted Mean ..		..	0·095	13·9	0·31
Weighted Means for full Profile all Sites—					
Virgin			·094	24	·26
			·078	12	·17
			·108	4·9	·23
		Totals	·280	40·9	·66

Cultivated	·079	16	·36
	·092	34	·29
	·107	8·8	·34
Totals	·278	58·8	·99
Reverted	·067	18	·29
	·076	19	·14
	·095	13·9	·31
Totals	·238	50·9	·74
Significant differences between totals (5 per cent level)	N.S.	N.S.	·23

The analyses show the general ferility status of the soils under consideration to be as follows:—

Nitrogen—Good
Available Phosphate—Low to very low
Available Potash—Satisfactory.

This means that whereas fertilizers providing nitrogen or potash may not be needed, at least for the first crops grown, it is almost certain that phosphate will be required especially at Qeledamu. The Qeledamu soil is also very acid and may respond to lime.

In passing it may be noted that the initial decrease of phosphate in going down the profile is, in nearly all cases, followed by the restoration of a level of phosphate comparable with or better than that of the surface soil. This phenomenon, which seems common in Fiji soils, may do something to explain the lack of phosphorus—deficiency symptoms on plants growing in soils having such deficient surface layers.

RESULTS.

For the interpretation of the complete data the summary at the end of Table II should be consulted. This makes use of the replication obtained through working with three different sites. The apparent changes shown in the body of the table for individual sites cannot be confirmed statistically, owing to a single profile only having been examined at each site. The weighted mean has been calculated to take cognizance of the difference in depth of soil to which the various analyses apply. It therefore gives a true mean for the whole profile at any given site. Since this mean refers to four feet of soil, its absolute value should not be interpreted in terms of standards applicable to surface soils.

A statistical examination of the data in Table II shows that the apparent difference in nutrients after cultivation could have been due to chance except in the case of available potash. Here the cultivated plots were significantly higher than both virgin and reverted plots, and it must be concluded that cultivation had brought about a definite release of potash to the soil.

The investigation shows that this form of cultivation has preserved the original level of soil fertility. It is in marked contrast to the effects of 150 years of continuous cultivation on Pitcairn Island reported by Grimmett(2). Here an originally rich volcanic soil had been so depleted that the total nitrogen had been reduced to 60 per cent of its original value, and available phosphate and potash to less than 10 per cent.

It should be noted that under the Fijian system of shifting cultivation no fertilizing materials of any kind are brought on to the land being cultivated.

There are large tracts of similar land in the wet zone which are at present being cultivated in the same way and it is reasonable to suppose that the results observed at the three sites investigated will be applicable elsewhere under the same conditions.

The change from this conservative regime to modern exploitation must be accompanied by a corresponding knowledge to allow of the economic use of the land while still safeguarding it in perpetuity.

RESULTS OF PINEAPPLE GROWING IN THE DRY ZONE

This was a study of the results of continuous cropping to pineapples on the C.S.R. Co's Lega Lega Estate near Nadi.

Three sites were chosen; two were on cropped land, and the third was on adjacent virgin land of similar elvation. Table III shows the relevant information. These sites were on rolling land with slopes of about 10 to 20 degrees. Rainfall is about 60 inches per annum in this region, with a more pronounced dry season than in the wet zone. The vegetation of the virgin land consisted of grasses and low herbs. In some cases tussocky grass clumps were separated by soil carrying only a cover of moss. Guava shrubs (*Psidium guayava*) had encroached at the lower end of the slope. The provisional soil map shows the soil type as Nadi clay.

TABLE III

HISTORY AND DESCRIPTION OF DRY ZONE SITES.

Information	*Virgin Area*	*Cultivated Area*	*Cultivated Area*
Location.	On west slope from labour lines. Same contour level as block 48.	Block 48B Three cycles of cropping and one ratoon).	Block 48AR. Three cycles of cropping and one ratoon).
History.	Never cultivated.	Grubbed out 1951. Rested 12 months before sampling.	Grubbed out 1952. Rested 6 months under Mauritius bean before sampling.

As before, the soil was sampled in order to assess any changes in fertility which may have taken place. Seven samples were taken from the arable layer of each block and these were analysed separately so that a reliable estimate of the true mean could be made in each case.

TABLE IV

SOIL ANALYSES—DRY ZONE.

Soil Test	Virgin Area	Cultivated Area (Block 48B)	Cultivated Area (Block 48AR.)
pH.	5·4	5·4	5·7
	5·3	5·4	5·7
	5·0	5·5	5·6
	5·2	5·5	5·6
	5·3	5·7	5·5
	5·5	5·6	5·8
	5·4	5·4	5·5
Total Nitrogen (per cent)	0·043	0·024	0·051
	0·111	0·065	0·063
	0·054	0·064	0·071
	0·025	0·084	00· 49
	0·094	0·045	0·049
	0·088	0·038	0·065
	0·064	0·058	0·051
Mean	0·068	0·054	0·057
Available Phosphate (p.p.m.)	8·4	9·1	13·3
	11·2	17·0	15·7
	2·7	12·5	14·7
	8·5	10·3	10·1
	11·6	10·9	11·2
	13·4	6·7	7·1
	19·9	8·3	13·7
Mean	9·8	10·7	12·3
Available Potash (m.e./100g.)	0·62	0·19	0·29
	0·86	0·22	0·18
	0·66	0·20	0·37
	0·35	0·15	0·24
	0·58	0·23	0·23
	0·74	0·24	0·35
	0·66	0·30	0·30
Mean	0·64	0·22	0·28
	0·1 per cent level	1 per cent level	5 per cent level
Significant difference between Means—			
Nitrogen	N.S.	N.S.	N.S.
Phosphate	N.S.	N.S.	N.S.
Potash	0·20	0·14	0 10

RESULTS

The general fertility status of this soil in its virgin state is as follows:—

Nitrogen—Low
Available Phosphate—Very low
Available Potash—Good to very good.

It is clear that there has been a decrease in the available potash due to cropping. This result is statistically significant at the 0·1 per cent level. At the same time available phosphate appears to have been slightly increased whilst nitrogen shows a slight decrease. Neither of the latter effects could be shown to be significant. These results can be understood in the light of the cropping history of the estate.

The C.S.R. Co. has found that, on these soils, heavy fertilizing with nitrogen and super phosphate is necessary in order to obtain a crop. The standard application is $6\frac{3}{4}$ cwt. ammonium sulphate and $5\frac{1}{2}$ cwt. super phosphate. Experimental results with potash fertilizer have in the past been somewhat uncertain and potash is not at present being used; but it now seems clear that the very large demand for potassium which is characteristic of the pineapple plant has now begun to tell on these soils in the absence of potash in the fertilizer mixture.

Field trials to confirm that a need for potash has developed on these soils would probably be well worth while both from the point of view of immediate returns and from the long-distance view of the maintenance of the fertility of the soil.

This is supported by a recent fertilizer trial carried out by the company in which, contrary to all estate experience, four units of superphosphate failed to give any better yield than two units, presumably because potash has now become the limiting factor.

DISCUSSION

The growing population of Fiji and the trends towards higher standards of living require greater production from the soil than the old system of shifting cultivation could supply. Land is too scarce to allow of bush fallows of several decades duration.

Information of the kind revealed in the present work is essential before any schemes for changing the ancient pattern of Fijian land usage for a modern one can be propounded rationally. It is necessary to know what the old system of subsistence agriculture did to the soil, and also what new ones of a modern exploitive nature may do if due precautions are not taken.

Exploitation and conservation are not necessarily incompatible and they have indeed been shown in some aspects of the present study to have gone hand in hand. Where this has not been so, the fact has been pointed out.

It is hoped that further information on the maintenance of soil ferility in Fiji will be available soon.

SUMMARY

1. A chemical investigation has been made of the changes in major plant nutrients in the soil under two kinds of land use in Fiji: namely,

(*a*) Native shifting-cultivation in the wet zone.

(*b*) Commercial pineapple-growing in the dry zone.

2. Under shifting cultivation the levels of phosphate and potash have been well maintained but the nitrogen level has fallen.

3. Commercial pineapple-growing has slightly improved the low phosphate level of the soils, but a need for potash fertilizing has now been indicated.

REFERENCE:

(1) *Laboratory Manual* Bureau of Sugar Experiment Stations, Queensland 2nd Edition (1939).

(2) Grimmett, R. E. R., New Zealand Department of Agriculture Annual Report 1937/8.

ECONOMIC BOTANY . . .

HYBRID DWARF COCONUT

The palm illustrated is a young Malayan dwarf x *Niuleka* hybrid approximately eight years old. It is one of the F 1 generation hybrids resulting from the hybridization work carried out by Mareschal(1). The measuring rod is 10 feet long

Photo: B. E. Parham.

which is the approximate height of the crown above ground level. The yield of nuts indicated in the photograph is by no means unusual in the case of these hybrid palms which have been much sought after during the past few years.

B.E.V.P.

(1) Mareschal, H.—*Obs. and Expts. on the Coconut Palm in Fiji, Agr. Journal,* Vol. 1, No. 2, 16—1928.

A USEFUL GREEN VEGETABLE

Basella alba.

Amongst recent introductions at Naduruloulou was a small quantity of seed of the Indian or climbing spinach known also as "Poi" (F.D.A. No. 13836). The plants raised from this seed proved to be quite different from those usually grown in the Colony, the

Fig. 1: Basella alba (F.D.A. 13836) at Naduruloulou—a gigantic form of the Indian spinach.

stems and leaves are much larger and heavier, indeed the whole plant is abnormally large and prolific (Plate 1). Seeds from the locally grown plants, grow true to the characteristics described above and provide a very large crop of succulent greens for domestic use. Seed in available in limited quantities.

—B.E.V.P.

ENTOMOLOGY . . .

THE RHINOCEROS BEETLE, ORYCTES RHINOCEROS

CERTAIN FACTORS WHICH MAY TEND TO INHIBIT ITS INCREASE OR CHECK ITS SPREAD IN FIJI

BY HUBERT W. SIMMONDS, O.B.E. *

The Asiatic Rhinoceros beetle, Oryctes rhinoceros L., gained access to Fiji some time prior to 1953 *being already firmly established, and in some numbers, in several localities when discovered in March* 1953. *All these localities were within a few miles of Suva, but one or two odd examples and some damage marks elsewhere suggested that it was already considerably more widely distributed.*

In order to combat the menace to the coconut industry as efficiently as possible, a Committee consisting of representatives of those most interested in this crop was formed under the chairmanship of the Director of Agriculture, and the writer was asked to assist in the work on a part-time basis.

TERMS OF REFERENCE.

Since it was felt that the distribution and spread of the pest formed such a different pattern to that which it did when it reached Samoa as to suggest that there might be some agency or factor operating in Fiji which was not present elsewhere and which was having an effect in this respect, the writer was instructed to try to ascertain whether any such agency did exist and if so to evaluate it. It would be well to say at once that no such outstanding agency was discovered, nor anything to suggest that any such agency might exist.

The general work of controlling the pest was taken over by the Senior Entomologist, Mr. B. A. O'Connor, and the sanitary gangs working under the supervision of Mr. Stokes proved so efficient that it was soon found that all suitable breeding places in the Suva district had either been destroyed, or rendered unsuitable from the writer's point of view by being treated with chemicals, so that it became necessary to create special compost heaps which would be reserved and not be treated by the sanitary gangs. For the same reason all work in the laboratory had to be carried out with grubs other than *Orcytes*, those generally used being two species of *Lucanidae* (*Aegus* spp.) as being the ones most easily obtained for the purpose.

CLIMATE

The method adopted was to search as many situations as would be used by the beetle for breeding purposes and to collect anything of a predatory nature found in such situations and test out in the laboratory with these other grubs whether such predators would be interested in beetle grubs.

Before going into the details of these tests it would be well to say something on the climatic side of the problem. It had been suggested that the climatic conditions in Fiji, being cooler than those prevailing in most parts of the beetle's distribution, would tend to slow up the breeding, and not only to reduce the number of generations in the year, but also, in this way, to expose the grubs to danger from their enemies for a longer period.

The discovery, however, of third instar grubs in a new compost heap which was under three months from date of construction, suggested that the beetle might, in the field, be capable of going through its early stages more quickly than experiments in the laboratory had indicated, whilst the wide distribution of the genus, from Southern Europe in the north to Delagoa Bay in the south, showed a wide climatic tolerance for the group as a whole.

* Formerly Government Entomologist, Fiji.

SUITABLE BREEDING PLACES IN FIJI FOR THE BEETLE, AND THE PREDATORY AGENCIES FOUND IN THESE SITUATIONS.

Sawdust piles.—Whilst the normal breeding place for *Oryctes* in Fiji would, as elsewhere, be rotting coconut and other palm logs and accumulations of rotting vegetation, the work of the controlling committee has been so efficient anywhere near Suva that any such suitable breeding media in this locality would be hard to find to-day. The piles of sawdust attached to the numerous sawmills along the coast constitute the greatest menace and also form the most difficult problem to control. Frequent search of these heaps has failed to disclose the presence of a single predator of any kind inhabiting them.

Compost pits and heaps.—The writer was fortunate in having several compost heaps in his own garden and these have not been treated with any insecticide but have instead been gone through every third or fourth week, thus giving some indication of the forms of predatory life likely to occupy such situations. A number of extra heaps, especially constructed for the purpose and placed elsewhere, have helped to give a wider range of the possible fauna.

Centipedes.—In some localities small centipedes, up to five inches in length, were not uncommon in these heaps and laboratory tests showed that these predators would destroy at least one half-grown Lucanid grub every forty-eight hours. A larger specimen could manage five or six in the same time, but these large centipedes are seldom found in compost heaps. Unfortunately the introduction of the Surinam toad, *Bufo marinus*, has greatly reduced the numbers of these predators in this country.

Predatory beetles.—The only predatory beetle found was a rather small *Staphylinid* which was in a compost heap situated near some jungle, a second one being observed at the same place, but this evaded capture. This small beetle continued to eat one grub every twenty-four hours for several weeks and it is felt that this group of predators offers encouraging possibilities.

The *Histerid, Platylister chinensis*, introduced from Java for the control of houseflies was found in a pile of rotting logs on one occasion. As the writer found this predator concentrating against *Oryctes* in Samoa, where it had also been introduced, there is no doubt that it would also do the same here, but the utter absence of beetle grubs of any kind in these piles and heaps would not render them attractive to these predators at the present time.

Carabidae.—Never common the few small forms of these predatory beetles found in Fiji have become exceedingly scarce since the introduction of the toad, and none have been observed in any of the compost heaps.

Thanks to the good offices of Dr. David Miller of the Cawthron Institute of New Zealand, a small colony of a large *Carabid, Mecodema spinifer*, a native of that country, was sent to us for trial. They were some time on the journey, which they did not survive too well, but as anticipated the survivors attacked the grubs used for testing purposes greedily, destroying over a hundred before the last passed out at the end of about a week. It must however not be assumed that this predator would be an answer to our problem, but it does seem probable that amongst the vast numbers of this predatory group there might be some which would prove of considerable value in the struggle which lies before us.

Dermaptera (Earwigs).—The big black earwig, *Chelisoches morio* Fab. was fairly common both in piles of logs and compost heaps and as the writer has recorded this species as devouring Scale insects in Tahiti(1) it was thought possible that it might occasionally attack small beetle grubs. The first trials were negative, but a later one suggested that under certain circumstances it might do so. As this species feeds at night the mere fact that a grub was dead did not necessarily indicate that the earwig had killed it, unless it was macerated. There is no doubt, however, that the last example tried was killed and partially eaten by this predator. It adds one more to the list of predators found in situations used by *Oryctes* as breeding media, but from a practical point of view would, in the writer's

opinion, be of no importance. Whilst the above remarks apply chiefly to compost heaps and similar collections of rubbish, it is probable that in natural conditions the normal breeding media of *Oryctes* consists of rotting logs, especially those of palms, and much time was therefore given to searching in such situations. It was therefore of great interest to find on more than one occasion the *Histerid, Plaesius javanus*, in old sago logs, where they had apparently been attracted by the presence of grubs of a small species of *Calandra* (*Curculionidae*, Weevils). There is no doubt that this predator would also attack small *Oryctes* grubs were these present.

Scorpions.—Under loose bark and generally throughout rotting logs one came across a small scorpion, which when tested, was found to eat at least one grub of from one to one and a half inches every forty-eight hours. These predators were never found in compost but, so far as they go, they would no doubt be useful.

Ants.—A very aggressive black ant, *Odontomachus haematoda Linn.* or near ally (name kindly supplied by the Senior Entomologist, Mr. B. A. O'Connor) was present at the bases of many rotting logs in the jungle whilst the same ant quickly invaded compost heaps placed in similar situations. Tests carried out with this ant showed that it attacked and killed, even full grown grubs when these were placed in its haunts. This species is not in any sense an enemy of *Oryctes* or other beetle grubs but it resents the intrusion of any form of animal life into the neighbourhood of its nest and in doing so renders a considerable quantity of rotting wood, which would otherwise be suitable, useless as a breeding media for the beetle, and it seems probable that any grubs resulting from eggs laid in the vicinity of their nests would have little chance of survival. It was, however, unable to cope with the hard shell of adult *Oryctes*.

GENERAL

Toads.—Tests showed that the toad, *Bufo marinus*, was not interested in either grubs or Adult Rhinoceros beetles, the shell of the latter probably proving too hard.

Mongoose.—As one would expect, this animal ate grubs freely as it will almost anything in the animal line. Mongoose or close allies are abundant in all the home countries of the genus *Oryctes*, except Madagascar, and have never even appeared to check its numbers and it is not thought that these mammals have had any bearing upon the present position of the beetle in Fiji. Further they are numerous in gardens, yet the writer has never known them to actually enter his compost heaps; although there would, at times, be other things to attract them. All in all this animal has proved a most disastrous introduction into Fiji and its further spread is certainly not to be encouraged.

Rats.—These enter and make their nests in the compost heaps where they would doubtless eat any grubs they came across, but they are hardly an animal which one would like to see protected.

PARASITES

Naturally with a new introduction, as *Oryctes* is to Fiji, one would not expect to come across specialised parasites; but the Senior Entomologist informs me that a number of grubs which he was breeding were destroyed by the Green Muscardine fungus (kindly identified by the Plant Pathologist, Mr. R. B. Morwood).

CONCLUSION

The very dry season has retarded the work very much and many of the special compost heaps are not even yet ready for examination. No major agency has, however, been found which can be said to be holding this pest in check in Fiji. All of those enumerated above come under the heading of "general environmental pressure", which pressure is probably far more severe in the homelands of the beetle and there seems no reason why this pressure should not be greatly increased in Fiji; in fact by the elimination of their own enemies some of the predators should become more efficient here than in their own countries. None the less there is going to be a severe snag in the work of introducing many possible useful predators due to the presence of the toad here, particularly will this be the case with ground beetles (*Carabidae*).

ADDENDUM

Since the above report was prepared the larva of an Elaterid beetle, almost certainly that of *Photophorus jansoni*, a somewhat scarce click bettle, some one and a quarter to one and a half inches in length, which has two luminous spots on its elytra, has been tested. This insect was found in a damp spot in the garden, where there was some rotting wood and other stuff thrown down from an adjoining new building, suggesting that the reason that it has not been found previously has been due to the excessively dry weather of the past five months.

This larva was sluggish at first, but after casting its skin became very active and attacked Lucanid grubs freely, having since then in nine days destroyed thirty grubs, of which about half seem to have been completely eaten, whilst the others were sometimes only killed. In the check not one grub died in the period.

Whilst this species is not sufficiently abundant to be of economic value at present the observations indicate that larvae of this group are amongst those which could be looked to as likely to be of probable value, the two main considerations being that the larvae should inhabit the same type of media that the *Oryctes* grubs make use of and also that it should occupy the same horizon in that media.

REFERENCE:

1 H. W. Simmonds, 1925, Bull. No. 19, Dept. Agric., Fiji.

NOTES ON APHIDS FROM COCOS NUCIFERA

BY D. HILLE RIS LAMBERS, BENNEKOM, NETHERLANDS

The Department of Agriculture is indebted to D. Hille Ris Lambers, who is an authority on the Aphids, for this original contribution on the taxonomy of aphids found on coconut palms. The paper describes two new species, and assigns to the genus Astegopteryx certain other species which were formerly placed in the genera Oregma and Trichoregma. Correct determination of these insects is, of course, of importance to local agriculture because some of them are severe pests of coconuts and other palms. Editor.

Three species of Aphididae are generally recorded from *Cocos*, viz. *Oregma* or *Trichoregma nipae* v.d. Goot, *rhapidis* v.d. Goot and *Cerataphis lataniae* Boisduval. Examination of many samples showed that in fact there are two species of *Trichoregma* on *Cocos*, and that the common *Cerataphis* on Cocos is probably not *Cerataphis lataniae* Boisd. *Trichoregma* Tak. is a synonym of the older genus *Astegopteryx* Karsch.

TRICHOREGMA TAKAH., 1929 = *ASTEGOPTERYX* KARSCH, 1890.

In some papers on the inhabitants of aphid galls on Styrax spp. I (1931, 1932) mentioned, that the embryones inside the migrants differ very much from embryones inside the mothers and grandmothers of these migrants. It was suspected that these migrants went to plants of a different order and produced aphids which probably would be known under a different generic name. As experimental transfer work would have to be done in the tropics and no prediction about eventual secondary hostplants could be given, I chose another way to solve the problem.

Dr. F. W. Rappard of the Forestry Service of Indonesia undertook the collection of *Hormaphidina* from Java. He did this very efficiently and in the course of some years an enormous quantity of material was available for embryological work. A study of the embryones of "*Trichoregma*" species showed that they were very similar to the embryones inside migrants from the well-known galls of *Astegopteryx styracophila* Karsch, the genotype of *Astegopteryx*. Subsequently galls of *A. styracophila* with living inhabitants were sent over from Java by air mail and alate migrants were transferred to grasses where they produced larvae. Though these did not become adult, it could be established that the Bamboo aphid "*Oregma*" ("*Trichoregma*") *pallida* v.d. Goot is the same species as *Astegopteryx styracophila* Karsch, so that *Trichoregma* becomes a synonym of *Astegopteryx*.

Three types of galls from *Styrax benzoin* were received. A second type of gall, described by Docters van Leeuwen and Docters van Leeuwen-Reynvaan (1926) as No. 1203, of which the inhabitants had not been described, contained migrants which on *Kentia sp.* produced brown larvae. These larvae were very similar to first instar larvae of "*Oregma*" or "*Trichoregma*" *nipae* v.d. Goot.

Finally it was necessary to establish that there is also a return migration of "*Trichoregma*" from the secondary hostplants (Bamboo or Palms) to *Styrax spp.* I expected to find two morphologically different alatae developing on the secondary hostplant in each species, but could not find this. A study of embryones could solve this problem also. In some samples from Bamboo, otherwise similar alatae were found, of which some contained embryones with frontal horns, marginal wax-glands and a chaetotaxy similar to that of embryones inside apterae viviparae from Bamboo, but other alatae contained embryones with a chaetotaxy similar to that of embryones inside apterae in galls on *Styrax*, and like the latter had no frontal horns or wax-glands.

It is therefore apparent that *Astegopteryx* migrates, and that the various "*Trichoregma*" *spp.* are *Astegopteryx spp.* living in disguise on Palms and Bamboo. Of course *Styrax* is not essential for the existence of *Astegopteryx*, for in the tropics the species can maintain themselves easily on Palms and Bamboo.

ASTEGOPTERYX RAPPARDI NOV. SPEC.

Usually mixed with *A. nipae* (v.d. Goot), samples of this species were received from Sepang (Malaya), 14–VIII–'30, leg. Corbett, many localities in Eastern Java, leg. Rappard, and from Guadalcanal, 12–V–'50, leg. O'Connor, all from *Cocos nucifera*. Dr. Rappard writes me that the species lives in immense numbers on the undersides of the leaves, with up to 110,000 on one leaf. The aphids are grouped in clusters, with small spaces between the clusters. Infested leaves get yellow spots and the species may become a severe pest. The ant *Oecophylla smaragdina* visits the aphids in Eastern Java.

A. rappardi differs from *A. nipae* by the following characters:

A. rappardi nov. spec.

(*a*) Apterae viviparae
1. Abdominal tergites with mutually free sclerotic transverse bars.
2. Horns on the front acute, not acuminate.
3. Marginal wax-glands on abdominal segments I–VI irregularly arranged.
4. Cephalic wax-glands irregularly arranged, 6–9 per group.
5. Hairs very long.

(*b*) Alatae viviparae
1. Vth ant. segment with 10–16 rhinaria.
2. Embryones inside with the marginal wax-glands in irregular groups.

A. nipae (v.d. Goot)

(*a*) Apterae viviparae
1. Abdomen with a wholly sclerotic, smoky tergum.
2. Horns on the front acuminate.
3. Marginal wax-glands oval, with their longest axis parallel.
4. Cephalic wax-glands also in rows, 2–4 per group.
5. Hairs much shorter.

(*b*) Alatae viviparae
1. Vth ant. segment with 6–10 rhinaria.
2. Embryones inside with the marginal wax-glands in rows.

Dr. Rappard writes that in life the species differ as follows: *A rappardi* nov. spec. has a grey head and thorax like *A. nipae* v.d. Goot, but the abdomen is greyish brown instead of bright brownish red as in *nipae*. *A. rappardi* is more elongated than *nipae*, and the waxy fringe is shorter and less conspicuous. Alate *rappardi* are black, those of *nipae* have a greenish hue on the abdomen.

CERATAPHIS LICHTENSTEIN, 1882.

Just as in "*Trichoregma*" Tak. a migration to *Styrax* could be shown to occur in *Cerataphis* Lichtenstein. The methods employed were the same as those mentioned above in *Trichoregma*, but unfortunately it is not yet possible to state which species known as a *Cerataphis* sp. can be associated with a gall on *Styrax*.

The gall, which Docters van Leeuwen and Docters van Leeuwen-Reynvaan erroneously described as that caused by *Astegopteryx styracophila* Karsch contains inhabitants which I described as *Astegopteryx fransseni* H.R.L. Subsequent work with living migrants from this gall showed that they produce typical *Cerataphis* larvae. On the other hand alatae of *Cerataphis spp.* were obtained which contained embryones of the *Astegopteryx* type, besides alatae with "normal" *Cerataphis* embryones.

Consequently we may assume that *Styrax* serves as primary host for *Cerataphis* species as well as for "*Trichoregma*" spp.

It is generally assumed that *Cerataphis lataniae* Boisd. is a polyphagous species occurring in the tropics and in hothouses on Palms and orchids. In the course of nearly 25 years I have amassed a large quantity of material of *Cerataphis* from many countries, but so far I have never received the orchid-inhabiting species from other plants, nor species from Palms from anything but *Palmaceae*. As van der Goot has first pointed out, the morphology of the aleurodiform apterous females is very variable, but some characters are constant. The apterae of three economically important species key as follows:

1. (4) Front always with two horns and with on the underside a number of normal, thin hairs on small sockets.
2. (3) Hairs around the siphunculi very short, blunt, not much longer than the socket on which they are placed. Longest hairs on VIIIth abd. tergite (the semicircular, free-moving part of the abdomen above

the cauda) much shorter than the longest caudal hairs. On various *Palmaceae*.

Cerataphis lataniae (Boisduval).

3. (2) Hairs around the siphunculi rather long and fine. Longest hairs on VIIIth abd. tergite not, or hardly shorter than the longest caudal hairs. On various *Orchidaceae*.

C. Ochidearum (Westwood).

4. (1) Front with or without horns, but, in addition to normal hairs, always with 1–3 pairs of short dagger– or club-shaped hairs on the underside near the antennal bases. At least one pair of these hairs placed on blunt tubercles.

C. variabilis n.sp.

C. ORCHIDEARUM (WESTWOOD).

This species is also known as *Ceratovacuna brasiliensis*. It has been recorded from many tropical countries and from hothouses in Europe and North America, usually under the name *C. lataniae* (Boisduval).

C. LATANIAE (*BOISDUVAL*).

The species was originally described from Palms in a hothouse. Records of this species from Palms in hothouses in the more recent literature are rare. De Baehr (1920) who gave it the name *Aphis palmae* most probably worked with this species, collecting it from *Latania* in a Polish hothouse. Gillette & Palmer (1934) describe it as *Cerataphis lataniae* from Palms in Colorado, and their figure of the head of the aptera vivipara induces me to identify a sample of *Cerataphis* from *Cocos nucifera*, collected by Dr. Rappard at Banjoewangi, Eastern Java, 2–VIII–'48 as *C. lataniae* (Boisd.).

C. VARIABILIS NOV. SPEC.

Van der Goot (1917) described as *C. lataniae* a species which he evidently took from *Cocos nucifera*, *Areca catechu*, *Zalacca edulis* and *Kentia* sp. This insect would seem to be the common *Cerataphis* on *Cocos* and other Palms with a range extending from Africa to Fiji. The most conspicuous character is the enormous variability of the aleurodiform apterae, first mentioned by Van der Goot.

The species differs from the two preceding ones by the presence of dagger-shaped hairs on stout bases on the underside of the head in apterae. Two extreme forms of apterae occur, one much like those of *C. orchidearum* (Westwood), and one more like a normal aphid, with wax-glands present on only the last abdominal tergite, the front with very small horns or only with 2–4 (more lateral) tubercles, each bearing a dagger-shaped, thorny spine.

A more extensive description is to be published elsewhere.

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GENERAL . . .

RURAL HOUSING

BY B. E. V. PARHAM

For many years, the provision of housing for subordinate field staff stationed in country districts has been a major problem of the Extension Service in the Department of Agriculture. While not seeking to become involved in or responsible for any kind of construction work which could be better done by others, field officers have often had no alternative in the interests of efficiency and human welfare but to try and synthethise some kind of accommodation for their junior assistants, however temporary and unsatisfactory it might prove to be. Moreover, since agriculture can only progress in direct ratio to any improvements in the standard of rural life, extension services are also concerned with all aspects of rural living and are frequently faced with the need for improved buildings suitable for local small farms. Many solutions have been attempted, including the construction of the typical Fijian-type house, commonly called a *bure*—built on contract and sometimes modified in various ways by the provision of wooden floors, doors and push-out louvre windows. A few wood-and-iron single-room buildings of cheap construction, built nearly to the specifications, as to stud height and ventilation, laid down by the Health Authorities, have neither proved popular nor secure against storms. They represent the nadir of the Department's housing ventures—undertaken in an extremity.

As long ago as 1938, the whole question of the advantages and disadvantages of the so-called "native-type house" was investigated by a special consultant brought from Malaya for the purpose of advising on the construction of thatched buildings which were currently held to be most in keeping with local tradition, requirements and scenery. A few experiments were made but nothing satisfactory eventuated. Faced with the unavoidable construction of dormitories for Fijian students in training, the Department, even at that time, had difficulty in obtaining sanction to utilize corrugated fibro-cement roofing on a frame building with double plaited bamboo walls. Such buildings have, however, given good service; and are generally cool and hygienic. The war period (1939–1945) brought with it many opportunities to study variations in design and materials as used by a large number of local craftsmen from different "schools"; but wartime requirements were of a low standard and so were many of the buildings erected on contract, often under high pressure of time and even higher rates of payment.

Following the war, a not-unexpected change, probably somewhat overdue, took place in the prices of contract built thatched houses (*bure*). Pre-war a standard rate was £2 per fathom, i.e. a minimum standard five-fathom (30′ x 16′) thatched house could be built for the extremely low price of £10—plus a few nails and some *yaqona**. Such structures were of course, built of materials close at hand; round bush-timbers often of low durability being used for posts and frames, and the roofs and sides usually thatched with dry sugarcane leaves or with reed grass. They were frequently quite serviceable and in drier areas fairly durable,—one known to the writer lasting for ten years until totally demolished in the January 1952 hurricane. For staff quarters, such buildings required the additional provision of wooden floors, doors and shutters and also of a detached kitchen usually with a corrugated-iron roof and tank for drinking water. Such additions might cost £60 pre war; and the resultant quarters were the best type then available to junior officers in Government service.

While providing a comparatively reasonable standard of accommodation, these structures have many obvious disadvantages: deterioration, especially in wet areas

* The root of *Piper methysticum*, used traditionally.

is rapid; beetles attack thatch, bamboo rafters and timbers; and even if regular smoking is carried out, the useful life is not more than five years: and there is an ever present danger of demolition by fire or hurricane.

Consequently, when contract prices steadily advanced to as much as £100 for a five fathom *bure* without fixtures or floors—and when the supply of durable materials for construction ceased to be readily obtainable, it become necessary to consider alternatives. Much thought has, in recent years, been given to this problem and various alternatives have been developed and adopted.

Probably, the most promising of these is the Cottage type of pre-fabricated cement-slab house designed by Nettleton(1) and

Plate 1.—First concrete-based " bure " type house built at Naduruloulou, 1953. Floor space 780 sq. ft. : 2 rooms (18 ft. x 15 ft.) and enclosed verandah 30 ft. x 8 ft.—raised wooden floor.

currently under construction in many places. Each unit weighs approximately 45 tons and costs £600.

The following paragraphs describe briefly experimental housing of a different type undertaken before a decision was, or could be, known regarding the provision of permanent housing for field staff.

Following the 1952 hurricane in which the Department lost a number of *bure* type houses it became urgently necessary to provide accommodation for several families who had nowhere to live.

Staff meetings produced a plan of action, based on a sketch plan for a house which might combine the best features of Fijian

house design with strength, durability and cheapness, while retaining domestic features demanded by custom. It was agreed that the foundation and frame work should be provided from emergency funds and that the whole of the bamboo work and thatching would be done on a community basis by all members of the staff resident in the neighbourhood, working largely in out-of-office hours. The method of construction and the general appearance of the building is shown in the accompanying photographs (Plates 1 and 2).

Briefly stated, the building is a five-fathom *bure* constructed and bolted on a dwarf wall of concrete blocks, with double walls of plaited bamboo and roof of sago palm (*Soga*) thatch. A verandah eight feet wide is provided either fully or half the length of the house. Doors are placed so as to give access to sleeping quarters from outside and from the kitchen without the need to enter the verandah or " lounge ". The outer walls have tarred paper (malthoid) between the two layers of bamboo to reduce draught, and interior partitions are of

Plate 2.—Second house under construction at Naduruloulou—October, 1953 : showing bamboo wall panel and " Malthoid " wall lining—also gable ends being thatched with pre-treated sago palm thatch. Floor space 700 square feet—verandah lounge 20′ x 8′.

scraped reeds (*gasau*). All bamboo and thatching material is pre-treated with " Metalex " (Copper-naphthenate) or D.D.T. emulsion either of which, up to the present, appears to give good protection against destructive organisms normally found in these materials. The floors are adequately ventilated below and constructed of 9″ x 1″ or 6″ x 1″ sawn timber, single dressed, because concrete is found to be not at all acceptable. Windows of standard push-out louvre design are provided; and there is, of course a scope for further utilization of native materials in the construction of the upper walls and for framework.

Such structures may be subject to the criticism that they combine different styles and materials and conform to no established architectural tradition; but at least they remove one defect of the wholly "indigenous" type of house, the wall and king posts of which are dug feebly into the earth, subject to rapid decay, and unstable to the point of collapse during strong winds and soaking rain. The building described may, and possibly, will, lose its thatch in a hurricane; but such materials are usually readily available and can be replaced fairly quickly provided the frame-work is intact. There are, too, many reasons favouring thatch (whether grass or palm leaf) over corrugated iron—the house is easily cleaned, cool and convenient. Its construction is within the resources and knowledge of the majority of a people who are perhaps rapidly losing faith and skill in their own traditional house-building craft. The cost of such a building as that described in this note, complete with detached kitchen, is between £350–£400.

A third house, which differs from those illustrated in that the roof and upper walls are thatched with reed grass (*gasau*), in accordance with the custom of the locality, has recently been constructed at the District Farm, Ra.

A similar structure has been used successfully for a farm building at the Plant Introduction Station, Naduruloulou—where the added coolness associated with a thatched roof was desirable, to protect growing plants in transit.

The writer records acknowledgments to Agricultural Assistant Uraia Koroi, who supervised the construction of the first two houses; to Agricultural Assistant F. Raiqiso and his colleagues who carried out the major part of the actual work on walls, partitions and roof.

The photographs are by R. Wright, Esq., of the Public Relations Office.

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A COOL STORE AT SUVA WHARF

Now that the banana growing areas have fully recovered from the effects of the 1952 hurricane, fruit is coming in in ever increasing quantities and fruit that is of first class quality.

Shipments were made twice a month to New Zealand in early 1953, increasing to three shipments a month later to cope with the quantity of fruit offering. Total shipments for the year were 283,000 cases.

A very large section of the Fijian people living on the Southern and Eastern districts of Viti Levu is almost wholly dependent on the banana industry. It is a small grower industry and many thousands of growers receive ready cash at the fortnightly packing.

These fortnightly shipments are large—generally about 15,000 cases—but shipments of 18,000 to 20,000 cases are not uncommon. These large shipments are throwing a very heavy load on the transport industry, particularly the road haulers: to transport 12,000 cases from distance from up to 95 miles from Suva in a period of four days requires a lot of trucks which in many instances are only occasionally used between shipments.

There is work going on in bringing new areas into cultivation of bananas. These are the island areas which do not now ship bananas overseas. Although some of these island areas have been worked in the past they have been rather risky ventures due to bad weather, engine breakdowns, etc., causing delays to the cutters which have arrived in Suva too late for the overseas vessel.

Because of the large quantities being shipped and the transport problems, fruit is being packed earlier and stands longer on the wharf in Suva. This means that much fruit is lost each trip, particularly in the summer months, because of ripeness.

It is to save the fruit from ripening, to ease the weight on the transport industry and to cope with the fruit from the island areas that it has been suggested that a cool store be built on the wharf in Suva, and a cool store would do all of these. Also it would hold the fruit at a constant temperature to be delivered into the refrigerated holds of the carrying vessel within the matter of minutes, and so a better product of even quality is delivered to New Zealand.

The main purpose of such a cool store would be to pre-cool the export bananas. There may be times, however, when importers may request space in the store to hold quantities of imported fruit and vegetables. Also a low temperature chamber might be required to store frozen meat and fish. At the moment this is handled by the local freezers, but Government may be asked to provide this facility when building a cool store. The bananas would, of course, be delivered to the store in green condition.

Bananas in Fiji are all handled in cases 26 inches long by 12 inches wide and 12 inches deep, outside measurements. The lid of the case has a bulge in the centre of from $1\frac{1}{2}$ inches to 2 inches. Each case contains about 75 pounds nett weight of fruit.

It is considered that the capacity of the store should be for at least 20,000 cases, made up of five or six chambers of equal capacity. At the moment between 2,000 and 2,500 cases arrive at the storage sheds in 24 hours for shipment, i.e. fruit brought in by road. When the river shippers' fruit arrives at the wharf they very often have 4,000 or more cases in the punts, which means the daily intake would rise considerably. An average for a shipment would be about 4,000 cases per day.

When the carrying vessel arrives the cool store will need to be emptied and the vessel loaded within 24 hours.

In view of this the store must be located on the wharf with loading ports on both sides of the store. This means that fruit brought in by truck can be loaded into the store by one door and discharged out through the other doors on to the dock at the ship's side. It is imperative that the cool store be located on the wharf so that when loading the fruit is exposed to atmospheric temperatures for the shortest possible time.

It is possible that the store need not attempt to cool the bananas to that temperature at which the fruit is carried in the Union Company's vessels, viz., 53°F., but that a

temperature of 60° F. might be sufficient to delay ripening; at the higher temperature there would be no risk of chilling the fruit.

Messrs. Ellis, Hardie, Syminton, refrigeration engineers of Wellington, have offered to provide the equipment for a pilot plant at Suva and their offer has been accepted. This will enable experiments to be carried out in Suva on the optimum temperature, humidity and air circulation rate for bananas delivered at Suva from the various districts at different seasons of the year. It is believed that season and locality both affect the quality of fruit and that variation in holding temperature and other conditions may be found necessary.

—C.H.

LAND DEVELOPMENT . . .

DEVELOPMENT OF SCHOOL FARMS IN FIJI

2—PASTURE IMPROVEMENT AND GENERAL DEVELOPMENT

In the Department's Annual Report for 1952 (1) *reference was made to the field projects and demonstrations instituted at the four principal Government Schools in collaboration with the authorities of the Department of Education. These farms comprise a total area of some* 1,700 *acres.*

At the Teacher's Training College farm, Nasinu work by the Weed Control Services was concentrated on the pasture areas and involved the eradication and spraying of weed growth over 80 acres and the establishment of superior grasses and the general improvement of pastures. This work was continued during 1953 and an account of the progress made will be given in a later note in this series.

At Queen Victoria School farm, the Southern Division Extension services dealt with soil conservation work, 25 terraces, 7,401 feet in total length averaging 24 feet in width were constructed on an area of five acres. The planting of pineapples, sweet-potatoes, tapioca and cowpea as the principal crops established a rotation regime for this area. A large number of useful and ornamental trees were also provided.

During 1953, the Weed Control services concentrated on the pastures at Queen Victoria School and at Ratu Kadavulevu School. In collaboration with the farm overseers they cleared extensive areas heavily infested with shrubby weeds; and established altogether nearly 30 acres of Batiki blue grass both by sowing seed and planting roots.

At Adi Cakobau School, development work comprised the clearing of new land, eradication of weeds, drainage works including the straightening and diversions of water courses and the construction of farm buildings. Details of the new dairy were given in a previous article(2); the present notes deal with further improvements effected at the School Farm during 1953 by the Weed Control and Field services working in collaboration with the Farm Overseer of the School Farm.

Pastures.—During 1952 some 10 acres of Batiki blue grass pastures had been established and 50 acres of natural pastures improved by mowing, discing and levelling. This work has been continued and extended: a further area of 23 acres of new land (mostly heavily infested with hibiscus burr, prickly solanum and lantana) was cleared. Some 106 chains of drains were dug, assisting largely in the control of the heavy sedge growth in low-lying areas and three acres were sown with grass and legume. Levelling by disc-harrowing, ploughing and grading with Ferguson equipment was carried out; and with the help of a D2 Caterpillar tractor loaned by the Principal Ratu Kadavulevu School, an extensive area of new land broken in. These areas were then sown down with a grass—legume mixture consisting of Batiki blue grass, eight pounds and *Centrosema* 20 pounds per acre.

Weed control trials using T.C.A. and Shell weedkillers were instituted with particular attention to the extensive clumps of sedge* which are characteristic of many pasture areas in the wet zone of Fiji. Other weedkillers used for trials and demonstrations were Weedone Standard, Phenoxyl 30, Weedone 57 and Weedone Brushkiller. Result of these trials will be given elsewhere.

* *Cyperus pennatus* and associated species.

Plate 1.—The " Weedmaster " low volume spray equipment mounted on Ferguson tractor for weed control in pastures.

In the course of follow-up work with weed control in pastures at Nasinu Training College and Adi Cakobau School—the newly acquired I.C.I. " Weedmaster," low-volume sprayer was used. (Plate. 1.)

This power machine mounted on a Ferguson tractor gives a coverage of 24 feet in width—its use was demonstrated in a number of places. Using Phenoxyl 30, excellent control at early stages of growth (up to 2 feet) of the following weeds has been recorded: blue rat tail, tarweed, hibiscus burr, tobacco weed, prickly solanum and lantana.

To provide a constant supply of chop fodder for concentrate feeding during milking, an area (1 square chain) of Guatemala grass[1] interplanted with tropical kudzu[2] was established close to the milking-shed. The yield of green fodder from this plot is high, providing adequate material for daily bail feeding of all milking cows.

Three acres of hillside land were cleared, burned off and sown with *Batiki* blue grass (8 pounds per acre) to provide an emergency grazing area for use during flooding of low lying fields.

Shade trees and live fences.—Much of the flat area of the farm lies in a valley—the new grazing areas were lowlying and swampy —requiring quite extensive drainage and water control—and liable to flooding during heavy rains. The use of live fences for subdivision was therefore advisable.

In swampy sites Vutuwai[3] and in drier sites Drala[4] were planted as live fence posts. The former has the disadvantage that the foliage is very susceptible to damage by the Indian rose beetle[5]—for control of which even spraying with D.D.T. solutions did not prove markedly successful. For

[1] *Tripsacum laxum*: [2] *Pueraria phaseoloides*:
[3] *Barringtonia racemosa*: [4] *Erythrina ovalifolia*;
[5] *Adoretus vestitus*,

shade, trees were planted in corner of fields—along boundaries and near water troughs. The trees established were padouk[6] and pink trumpet tree[7]. Native trees left as shade were ivi[8], wild lemon[9], kavika[10] and dawa[11].

Fencing, Roads and Water Supply.—Pasture improvement work included the local manufacture of concrete fence posts and the erection of 66 chains of boundary and main fences and chains of subsidiary subdivision (wooden post) fences. A start was made with water supply to the grazing areas, by pipeline from the spring-fed reservoir built to supply the dairy. Extensions were made to three paddocks and to the calf-feeding pen. Three water troughs, of approximately 200 gallons capacity each, were constructed from discarded corrugated iron tanks lined with cement and fitted with automatic ball-valves to regulate the supply of water. (Plate 2.)

Plate 2.—Field water-trough made from discarded tank fitted with ball-valve intake. (Adi Cakobau School Farm, 1953).

In addition to the main farm road (30 chains) formed by the Public Works Department, 22 chains of access roads with necessary culverts, and swamp crossings were made, using the Ferguson grader terracer.

Calf-pen.—A covered, calf-feeding bail of simple design was constructed to ensure individual feeding under hygienic conditions. The pen has a concrete floor with gravel surround—the bails are standard type and the bucket stand utilizes two sheets of marsden airstrip matting suitable shaped to form a backed shelf. Rings of steel rod hold each bucket securely in position. For the roof of the shelter, bamboo tiles pretreated with "Metalex" (copper-naphthenate) were use. (Plate 3.)

Later, this roof was thatched over with preservatized sago-palm thatch, and leaves extended to give added protection from

[6] *Pterocarpus indicus*;
[7] *Tabebuia pentaphylla*; [8] *Inocarpus edulis*;
[9] *Citrus vulgaris*; [10] *Eugenia malaccensis*;
[11] *Pometia pinnata.*

driving rain. The calf-paddock was oversown with *Batiki* blue grass; and kept in good condition during the process of establishment by occasional mowing and spraying for control of weeds (mostly tarweed sedge and native paspalum).

Compost Bins.—The adequate disposal of kitchen and compound wastes is always a problem at institutions; usually, in Fiji, much time and labour is spent in digging garbage pits for the burial of refuse. Not infrequently these pits are far from hygienic in operation and certainly they represent the loss of valuable organic material from the farm and garden areas.

An attempt to meet this problem was made by establishing a battery of three composting pens made of ten strips of marsden steel matting on a concrete base—protected from the rain by a thatched roof. Each day the compound refuse is brought to the bins—spread out and covered with a six-inch layer of grass mowings and other weed refuse from the compound orchard or farm areas. The material is sprinkled as necessary with liquid manure from the dairy—and turned from one bin to the next at more or less regular intervals. (Plate 4.)

Plate 3.—Calf-feeding bails with roof of bamboo tiles at Adi Cakobau School Farm, 1953.

The compost made in these bins is used for the vegetable plots and the orchard area near by.

General Crops.—The selection, preparation and planting up of suitable areas for various food crops also received attention; and assistance given with the harvesting of rice crops (6 acres), provided an opportunity to carry out trials with the recently acquired miniature thresher-harvester machines.

The padi harvested from these fields was cleaned and winnowed by means of the Australian manufactured "Little Wonder" Winnower which has given consistently good results over many years wherever used in the Colony (Plate 5). It may be operated by hand or by powered belt drive. B.E.V.P.

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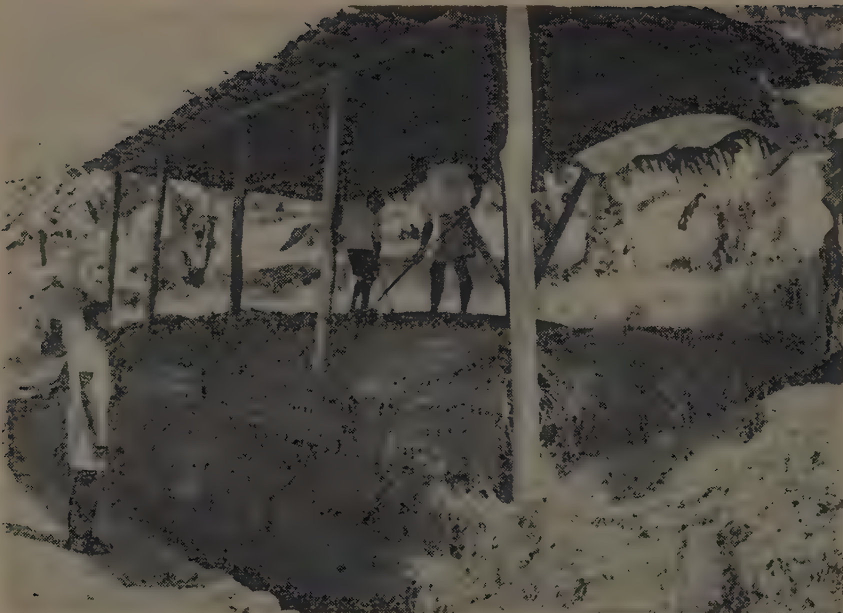


Plate 4.—Composting compound garbage, dairy and farm wastes.—Thatched roof of sago palm leaves. Adi Cakobau School, 1953.

Plate 5.—Hand operated winnower for cleaning rice padi, 1953.

RICE HARVESTING MACHINE

A PRELIMINARY NOTE

After prolonged negotiations three small rice harvesting machines were manufactured in Australia in collaboration with the Director-General of Agriculture, Canberra, as likely to prove especially suitable for Fiji conditions of small acreages often poorly drained at harvest time.

These were manufactured in Australia in collaboration with the Director-General of Agriculture, Canberra as likely to prove especially suitable for Fiji conditions of small acreages, often poorly drained at harvest time. (Plate 1.)

The machine is drawn by a tractor and the threshing equipment (rotary-stripper) is operated by a power unit mounted at the rear end.

The machine had not proved highly successful when tried out in uneven and weedy fields of rice at Tailevu so advantage was taken of the clean-weeded rice fields at Sawani where the flat topography was also favourable to operations of this kind. The crop was a heavy one of New Guinea variety and lodging due to rain squalls occurred in patches. The machine was operated easily when towed at a distance of 9–10 feet from the tractor, this giving a better manouvreability in stands of un-even height and yield. (Plate 2.)

The performance was fair to good in most parts of the field: a very high proportion of the grain being stripped with little loss, as seen on checking in the wake of the machine. The dropping habit of the rice inflorescence (grain heads) and their terminal leafiness together with uneven growth due to variations in soil moisture and fertility are factors which render mechanized harvesting somewhat difficult.

There was a tendency for weeds and culms of rice plants to choke the tynes and to become fouled around the bearings of the thresher, necessitating frequent stoppages.

In spite of these operational hazards, the field was harvested in good time; all lodged areas, as seen in plates 1 and 2, being harvested and threshed by hand.

The machine was also used as a stationary thresher with some success.

It is tentatively concluded that, in order to achieve satisfactory machine harvesting, care must be taken with the preparation of the field and with the cultivation and weeding of the crop in order to ensure a most even weed-free stand of more or less upright growth and uniform height. Nor can it be expected that the optimum results with a machine of this kind can be obtained until operators are thoroughly conversant with and skilled in its use and aware of its capabilities as well as its limitations.

Plate 1.—The "Lennon" stripper-harvester at work. Lodged rice is being harvested by hand (background).

Plate 2.—Harvesting with machine drawn well behind tractor in heavy crop of New Guinea rice at Adi Cakobau School Farm, 1953.

WEED CONTROL

A NOTE ON EXPERIMENTAL MATERIALS: ETHONE AND XY 2631

The results of experimental and routine use of hormone weedkillers indicate considerable success with the establishment of weedfree pastures as well as with the rehabilitation of overgrazed and weed infested lands. There is no doubt that spraying has an important place in these operations and if carried out at the optimum season and period of growth, the costs are not unreasonable. Some coconut planters are turning to chemical weed control and dispensing with the problems associated with the maintenance of large labour establishments. At the other end of the scale, small rice producers are unusually eager to borrow equipment and buy weed "killers" to spray their fields. The Department is doing all it can in both investigational and extension work to promote weed control and assist higher production. There is no doubt but that spraying for control of seedling weeds in pastures is both economical and essential, as complementary to mowing and other operations.

The following note refers to trials with two products supplied by Imperial Chemical Industries Ltd., England, for trial in Fiji.

Ethone.—This product was used at the concentration recommended for two types of weed:—

(*a*) Pasture weeds
(*b*) Guava scrub.

(*a*) The pasture weeds treated were all at early stages of growth, up 24 inches high; the species were:
Hyptis pectinata—Mint weed
Urena lobata—Hibiscus burr
Cuphea carthaginensis—Tar weed
Ageratum conyzoides—Goat weed
and the patches were dense regrowths on bare ground following the cutting down and burning of the original heavy weed growth.

The results were extremely satisfactory, complete control of all these species being achieved with not more than two sprayings spaced about two months apart. The spray was applied with a Rega Knapsack sprayer.

(*b*) The guava treated included small trees with trunks 3–4 inches diameter and the Ethone was applied by means of a Cornell tree-stabbing tool which injects a small quantity of fluid into a scar or cut made at each blow on the base of the tree.

Results were striking, the trees dropped their leaves and the bark of stem and branches cracked in a very marked pattern. All trees treated were dead three months after treatment; and there was no regrowth of shoots from the base. Control of guava scrub by mechanical means is difficult because of these shoots which grow out in numbers when trees are cut down or grubbed out.

Monthly trials carried out indicate that the treatment is most effective in the warm weather, but it is necessary to establish the optimum season for treatment. At the same time costs are being studied, as this is an important factor with landholders. To date this method of dealing with guava trees costs not more than £3 per acre.

XY 2631.—This material has been used also in the guava control trials using the stabbing tool.

ABSTRACT . . .

SUGAR IN FIJI*

The economic and social development of the Fiji Islands from the 1870's onward has been closely identified with the sugar industry. The present organization of the industry reflects the way in which Fijian and Indian ways of life have been adapted to the needs of western methods of production for export.

Market prospects for Fijian sugar are underwritten by the Commonwealth Sugar Agreement in which Fiji's quota is almost equal to maximum production.

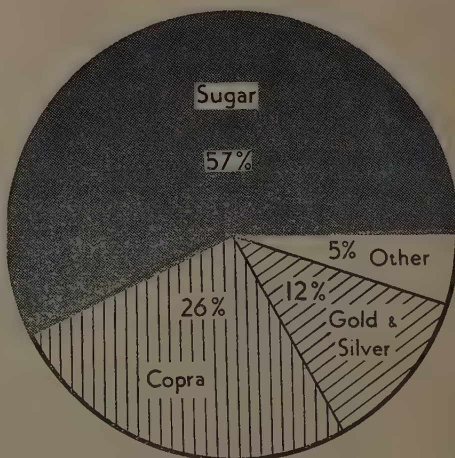
Sugar plays an even more dominant role in the Fijian economy than does wool in Australia. Last year sugar accounted for 57 per cent of the value of all exports from Fiji. Because of a particularly good season in 1953 and expansion of the area under cultivation to 102,000 acres, a record crop is expected, estimated at 190,000 tons of sugar worth over £7m., compared with the previous year's output of 132,000 tons, valued at £5·6m. No further expansion in acreage is contemplated at this stage, for the capacity of the mills has been reached and marketing of larger quantities of raw sugar would be difficult.

The present state of the sugar industry in Fiji represents the climax of over 80 years' varied experience and growth in difficult conditions. Changes were wrought in native life, immigrant labour was introduced, and, in addition, sugar as a world commodity has suffered from many sharp economic fluctuations. The present prosperity is due in large measure to the evolution of enlightened farming and tenancy methods by the Colonial Sugar Refining Co. Ltd., whose interests in Fiji have come to be regarded as synonymous with the Colony's sugar industry.

EARLY DEVELOPMENT.

Early in the 1870's, after the Fiji Islands became a British Crown Colony, sugar cane gradually supplanted copra and cotton as the main plantation crop grown by European planters. Native labour was introduced from the Solomon Islands, the Line Islands and New Hebrides, for the Fijian social system of community enterprise to satisfy immediate village needs was then, and still is, not readily adaptable to regular plantation work. Most of the Melanesian labourers were repatriated by 1877 and Indian labour was recruited by the Fijian Government and allotted to estates run by the sugar companies and European planters.

The indenture system required five years' service on an estate and another five years' residence in the Colony to qualify for a free return passage to India. In the 37 years until the indenture system was terminated in 1916, over 60,000 Indians were indentured



1952 Fiji Exports £9·9m.

*Reprinted from the *Bank of New South Review* No. 15 of November, 1953, by courtesy of the Manager, Bank of N.S.W. Suva. ED.

and about two-thirds elected to remain in the Colony. They were mostly Hindus who found that life in Fiji was a vast improvement on their former poverty and gave them social freedom away from some of the limitations imposed by age-old custom in India.

The Indian population increased rapidly and exceeded the Fijians in the 1948 census. In 1952 the population of the Islands totalled 313,000, of which 149,000 (48 per cent) were Indians and 136,000 (43 per cent) Fijians, with about 7,000 Europeans and the remainder Euronesian, Chinese and natives from other islands.

Sugar growing is confined mainly to the " dry " areas of the two main islands of the group, Viti Levu and Vanua Levu. Mountain ranges rising to over 4,000 feet run at right angles to the prevailing east to south-east winds, dividing the islands into the " wet " zone on the windward side, with an average rainfall of 120 inches at Suva, and the " dry " zone with a rainfall of about 70 inches at Lautoka. The " wet " zone is luxuriant tropical forest, difficult to clear and keep clear of secondary growth, while the " dry " zone is largely undulating open grassland with scattered trees. The river systems are extensive and important because much of the caneland and other agricultural land lies on their plains and adjoining slopes.

The first sugar mill was erected near Suva and others soon followed. The world slump in sugar prices during the 1880's caused many mills to close. Only three companies survived—the Fiji Sugar Co. at Navua, on the south coast west of Suva, the Penang Co., on the north coast, and the C.S.R. Co. with a mill at Nausori, which was established in 1880 on the Rewa River north-east of Suva, and another at Rarawai on the Ba River, north-west coast, established in 1883. The C.S.R. Co. erected the Labasa mill in Vanua Levu in 1894, and their mill at Lautoka first crushed in 1903. The Navua mill finally closed in 1922 and the Penang mill was bought in 1926 by the C.S.R. Co., which is now the only sugar company operating in Fiji.

SMALL HOLDINGS.

The end of the indenture system raised an acute labour problem for the plantations and mills. Many planters gave up, and gradu-

ally the C.S.R. Co. after various experiments evolved a system of leasing its estates in small holdings, mostly to Indians. It was found that 10–12 acres was as much as one family could cultivate without hired labour. The tenant's lease was drawn up in such a way as to safeguard the land from deterioration, produce the best quality cane, and prevent the tenant from incurring overburdening debt. Thus the system needed a great deal of supervision and organization of supplies and finance by the Company to mould the Indians into effective producers and satisfactory social groups in the life of the Colony.

The Company purchases sugar cane also from contractors cultivating land usually leased from the Native Land Trust Board. The contractors are again mostly Indians; the Company's field officers advise them on methods of cultivation and varieties to be planted, but have not the same control as with its tenants. In the past some contractors' lands have been over-cropped, but of recent years clauses have been inserted in leases to prevent misuse of lands and also trading in leases in an endeavour to forestall chronic indebtedness among the Indian farmers. In 1952 tenant farmers numbered 4,366, cultivating 49,553 acres, and contractors 5,476, cultivating 49,325 acres. Fijian tenants numbered 101 and contractors 1,042; almost all the rest were Indians. Only 2,661 acres remain directly under the Company's control and are used for cane experimental work and training grounds for field officers.

POLITICAL AND INDUSTRIAL PROBLEMS.

By this change to individual farming the industry has avoided establishment of a large class of landless wage-earning labourers, with its possibilities of periodic unrest. Yet with the success of the small-holding system have risen political aspirations among some of the Indians, which are expressed both in the industrial associations of cane growers and sugar industry employees and in general public life. The basic differences in the Fijian and Indian elements of the population may lead to new problems as the more politically minded Indians continue to

Indian cane-grower ploughing between young cane at Lautoka.

—Photo by courtesy of C.S.R. Co. Ltd.

increase in numbers and substantially exceed the Fijians as they appear bound to do in the next decade.

In 1943 the Colonial Office appointed Dr. Shepherd, the Carnegie Professor of Economics, Imperial College of Tropical Agriculture, [illegible]dad, to make a special investigation [illegible] arrangements between the C.S.R. Co. and growers and to determine if alterations or government intervention were necessary. His report of 1945 made a few suggestions for modification of existing methods, some of which have been carried out.

The Commissioner of Labour in a recent annual report summed up the industrial situation very aptly when he stated that the sugar industry provides a most successful example of collective bargaining. The C.S.R. Co. has adopted a patient and flexible attitude so that labour conditions in the industry are on an excellent footing.

OUTLOOK FOR PRODUCTION AND MARKETING.

Output of Fijian and Indian workers is low compared with that in more industrialized countries, and a large supervising staff is required both in the field and mills. The

Typical scattered sugar-growing areas in Fiji.
—Fiji official photo.

canelands are not concentrated in large areas but are scattered and require 440 miles of permanent tramline and 165 miles of portable line to serve them. The company provides free accommodation and medical attention for its employees and technical advisory services for its tenants and contractors. The soundness of its method in the social development of the Islands is a great achievement in the annals of free enterprise. Yet all these services add to overhead costs and must be reflected in the cost of production of Fijian sugar, which, however, does not differ very greatly from that in other Commonwealth countries.

Fiji's sugar is marketed by the C.S.R. Co. The main destinations of exports are western Canada and New Zealand, which took about 56,000 tons each in 1952, and the United Kingdom, which took 18,000 tons. Other smaller markets exist in the Pacific area, which, together with local consumption, account for about 12,000 tons annually.

During and since the war Fijian sugar was sold under contract ot the British Ministry of Food. This arrangement was superseded on January 1, 1953, by the Commonwealth Sugar Agreement, under which Fiji has an export quota of 170,000 tons. For 125,000 tons of the quota the price is nogitiated annually, taking into account movement of costs in all Commonwealth exporting countries, and was fixed at £stg.42 6s. 8d. per ton for 1953. The remaining 45,000 tons of the quota are marketed at world prices plus United Kingdom or Canadian preference. Any sugar produced in excess of the Commonwealth quota may have to be sold in competition with lower cost producers possibly outside the Empire Preferential area. If the recently negotiated International Sugar Agreement is ratified, however, the range of price fluctuations for " free " sugar will be limited.

The bulk of the Fijian sugar exports is guaranteed a market at least until 1960 under the Commonwealth Sugar Agreement. At each annual price review the agreement may be extended for another year. Thus Fiji will have five years' notice of any change in the conditions of sale of its principal crop. With this assurance of markets at prices which are at present satisfactory, no further expansion of production is contemplated because of the quota limitations; the sugar industry will be able to consolidate its present position and increase its efficiency in the growing and milling of the cane crop. This prospect of stability for the Colony's main industry should augur well for steady development and prosperity in Fiji.

RICE CULTIVATION—COSTED TRIALS IN TRINIDAD

Costed trials of rice cultivation carried out by Nanayakkara at the Imperial College of Tropical Agriculture in 1950 showed that the typical rice farmer and his wife used 236 man-hours per acre to till the soil for their crop. With the help of a rice-land rotary hoe " Gem ", the labour requirement was reduced to 50·3 man-hours (of which nearly 40 hours was the time taken to cut weeds, clean irrigation canals, etc.) and the area that a man could cultivate within the season was increased to a point where planting out (or shortage of land) became the limiting factor. For larger Farmers or contractors, the Fordson Major with a Rotavator attachment reduced the labour requirement to less than 10 man-hours.

Method	Est. Cost S B.W.I. cultivation	(S1.4.2) harvesting	Man hours per acre
1. Hand work throughout ..	2·61	0·46	469
2. Cultivation by animal; threshing by bulls and roller ..	1·46	0·35	327
3. Rotary Hoe "Gem" and Tullos thresher	1·74	0·67	262
4. Fordson Major Rotavator and I.H.C. thresher	1·21	0·48	199

Costings of this sort are always conditioned by local conditions. The Trinidad rice industry is characterised by peasant producers, small fields (usually regular in shape, but of various sizes) comparatively high rates of pay for wage-earners, comparatively high yields of rice.

Other applications of the rotary hoe seen in Trinidad rice fields include the David Brown unit on Goodyear rice-land tyres, and the Ferguson on wheel-girdles.

IMPORTATION OF PLANTS INTO AUSTRALIA

Local residents and oversea visitors frequently wish to take or send plants from Fiji to Australia without realizing the restrictions imposed by the Commonwealth authorities under the Plant Quarantine Regulations.

These regulations have recently been amended and it is now notified that the importation of all living plant material into Australia is prohibited except under certain conditions and restrictions which are described below. Plant material includes:—

(i) woody plants
(ii) seedlings of herbaceous plants, and
(iii) slips, cuttings, layers, runners offsets and similar material used for vegetative propagation of woody or herbaceous plants.

A person shall not import any such plant material into Australia unless:—

(*a*) he is an approved authority, i.e., a Department or authority of the State equipped for plant introduction work or a research organization or person registered by the Director; and

(*b*) he is the holder of a permit issued by the Director for the importation of such plants.

Before any plants may be landed in Australia the importers must be registered and must obtain a permit through the Chief Quarantine Officer in the State in which the plants are to be grown.

Under these new Regulations it is obviously inadvisable for any person not possessing the official authority and permit to attempt to take or send plants to Australia.

The Department of Agriculture, Fiji, will, in future, require to sight such permits before issuing Plant Health Certificates for plant material for Australian destinations.

LIVESTOCK AVAILABLE FOR SALE AT THE PRINCIPAL AGRICULTURAL STATION, KORONIVIA.

Cattle.

Friesian and Jersey bull calves—
Prices—from six months of age upwards one guinea per month of age.

Pigs.

Large white boars and gilts—

Prices—up to	4	months	..	£6
,,	5	,,	..	£7
,,	6	,,	..	£8
,,	7	,,	..	£11
,,	8	,,	..	£13
over	8	,,	..	£15

Poultry.

White Leghorns, Rhode Island Red and Australorps. Unsexed chicks, available from May to September—

Price—£1 per doz.; £8 per 100.

All sales are, by regulation, for cash only. Orders should be placed with the nearest office of the Department of Agriculture as far in advance as possible. Transport arrangements and costs are the purchasers' responsibility.

SUMMARY OF AGRICULTURAL STATISTICS OF THE PROVINCE OF KADAVU SHOWN BY DISTRICTS AND INCLUDING FIGURES FOR EXEMPTED MEN (FIJIANS) AND EUROPEAN-OWNED ESTATES.

District	Arable Land (ACRES)	Area Cultivated	Fallow	Perm Pasture	Land in Trees and Shrubs	Bananas	Coconuts	Dalo	Tapioca	Yaqona	Cattle (TOTAL NUMBERS)	Horses	Pigs	Ducks	Fowls	Spades, Post Hole and Digging	Forks Digging	Ploughs	Acres of Fruit Trees	Acres of Rice
Nabukelevu	1,910	1,479	431	591	482	45	762	235	167	61	10	5	668	110	1,001	460	54	..	87	..
Nakasaleka	1,730	1,492	483	49	336	39	673	215	103	135	4	5	292	4	1,014	385	103	1	99	..
Naceva	2,110	1,246	617	90	1,195	46	862	217	123	140	15	1	289	32	968	390	73	..	95	..
Exempted Men ..	..	675	..	..	..	19	437	49	15	61	14	..	179	17	411	95	29	..	12	5
Estates	913	518	449	228	454	11	238	19	15	19	28	10	54	..	465	53	17	1	..	13
Tavuki	3,343	2,243	1,098	128	1,815	67	1,437	251	155	92	35	9	887	67	1,358	633	148	..	137	2
Total ..	10,006	7,653	3,078	1,086	4,282	227	4,429	986	578	508	106	30	2,369	230	5,217	2,016	424	2	430	20

Root crops for Fijians take the place of rice for Indians. There is practically no capital equipment owned by these farmers other than forks and spaces.